U.S. DEPARTMENT OF AGRICULTURE

AGRICULTURAL RESEARCH SERVICE

PROGRESS REPORT
2001

GRAIN MARKETING AND PRODUCTION RESEARCH CENTER

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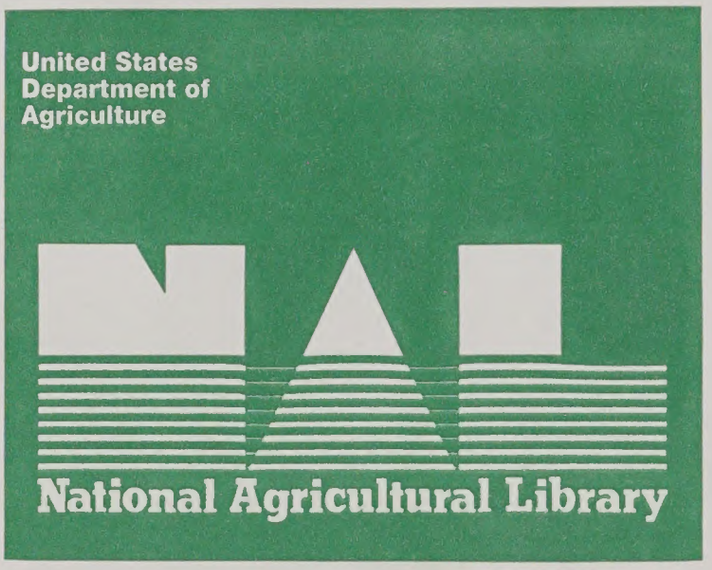
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WELCOME TO GMPRC

Since its establishment in 1970, the Agricultural Research Service's Grain Marketing and Production Research Center (GMPRC) has been the U.S. Department of Agriculture's main facility for conducting research on measuring and controlling the quality of cereal grains throughout the grain industry.

The Center focuses on solving food and agricultural problems in grain production and marketing, alfalfa production, and wind erosion control. Our research emphasizes maximal nutritional value, consumer acceptance, and end-use performance while conserving resources and maintaining soundness and overall quality during handling, conditioning, and storage.

Located in Manhattan, Kansas, GMPRC is situated in the heart of the Great Plains, which includes thirteen states, that produce more than 2/3 of all U.S. wheat, corn, alfalfa, and soybeans. Operating from a 60,000 square foot facility, and the nation's only 50,000 bushel (700 metric ton) capacity research grain elevator, the Center is composed of five research units:

- BIOLOGICAL
- ENGINEERING
- GRAIN QUALITY AND STRUCTURE
- PLANT SCIENCE AND ENTOMOLOGY
- WIND EROSION

Our VISION is to be **"The Customer's Choice in grain, alfalfa, and wind erosion science and technology"** and we welcome the opportunity to serve all segments of the grain industry from producers to consumers.

Dr. James E. Throne, Research Leader
Biological Research Unit

Dr. Floyd E. Dowell, Research Leader
Engineering Research Unit

Dr. Okkyung Kim Chung, Research Leader
Grain Quality and Structure Research Unit

Dr. Robert L. Bowden, Research Leader
Plant Science & Entomology Research Unit

Dr. Edward L. Skidmore, Research Leader
Wind Erosion Research Unit

Dr. Donald E. Koeltzow
Center Director

INTERACTIONS WITH KANSAS STATE UNIVERSITY

Kansas State University (KSU) has a world renowned reputation in many fields; however, they have an exceptionally strong program in agriculture. GMPRC maintains a very close working relationship with KSU and the Kansas Agricultural Experiment Station and Cooperative Extension Service. Two of the GMPRC research units, namely Plant Science and Entomology and Wind Erosion, are housed on the KSU campus and the Northeast Area Extension Offices are housed in the GMPRC facility. GMPRC scientists enjoy a very close working relationship with scientists at KSU. A majority of the GMPRC scientists have adjunct faculty positions and, as a result, approximately 40 undergraduate and graduate students conduct research at GMPRC each year.

A Special Note to Our Customers

We have had another good year at the Center in 2001. **1) Facility Renovation Continued.** Visitors to the Center will notice several significant changes. In order to meet new security requirements, a receptionist area was added to the main lobby. All visitors must now enter the facility through the main lobby and employees and visitors must now wear identification badges. The lighting in both parking areas was improved and we anticipate that construction on our new "Swing Space" addition will begin this spring. The Swing Space (approximately 5,000 sq. ft.) will be attached to the north wing of the main building and will be used to provide office and laboratory space while major sections of the main facility are being renovated under Phases III and IV. Eventually, this space will be used to house all of the Center environmental chambers so that these are more readily available to scientists. We are within $4.3 million of having enough funds to complete this renovation of our main facility. Hopefully, these funds will be appropriated in FY 2003. **2) Five New Scientists Join the Center Research Staff and Three Additional Vacancies will be Filled. Dr. Robert Bowden** was hired as the Research Leader for our Plant Science and Entomology Research Unit replacing Dr. Merle Eversmeyer who retired. Dr. Bowden is a plant pathologist and he comes to us from Kansas State University where he held a faculty appointment in the Department of Plant Pathology with additional duties in Agricultural Extension. **Dr. Ming-Shun Chen** was hired to replace Dr. Jim Hatchett. Dr. Chen was formerly a molecular geneticist at Washington University in St. Louis, MO and will continue with the Hessian fly research program. **Dr. Tom Pearson** joined our Engineering Research Unit in order to serve as the lead scientist for our Objective Grading and End-Use Property Assessment Program. Dr. Pearson is an Agricultural Engineer and comes to us from the ARS Western Regional Research Center in Albany, CA. **Dr. John Tatarko**, a graduate of Kansas State University in Soil Science, replaces Dr. Dean Armbrust, another recent retiree, in the Wind Erosion Research Unit. Dr. Tatarko will continue with research to validate the Wind Erosion Prediction System and with the development of training materials for this system. **Dr. Scott Bean**, a recent graduate of Kansas State University in Grain Science, was hired to fill the newly created position to develop new uses for grain sorghum.

In addition, we are actively recruiting for a molecular geneticist to lead our newly established DNA molecular marker analysis program for wheat, a replacement for Charles Martin in the Engineering Research Unit, and a replacement for Dan Skinner in the Plant Science and Entomology Research Unit.

On a sadder note, we also have lost another research scientist position in the Biological Research Unit (BRU). Dr. David Hagstrum retired from this Unit and will not be replaced due to a shortage of funds. The BRU is the national center of research work on insect problems in stored grain and processed cereal products and it also is the largest center for stored-product insect pest research in the world. Only a very few scientists outside of this unit work on these problems. This decrease lowers the number of scientists working on insect pest control in grain and grain products to 11 and is occurring at the same time that many of the fumigants and insecticides used for insect control in food and food production facilities are being lost.

This Progress Report is designed to provide you with specific information about each of the active research projects at GMPRC. Each major research project in the Agricultural Research Service, including those at GMPRC, is identified by a number from the Current Research Information System (CRIS). In addition, we frequently develop Specific Cooperative Agreements (SCAs) or Cooperative Research and Development Agreements (CRADAs) with other groups such as universities, other federal agencies, or private companies. All of the results from these various agreements are incorporated into the report for each of the specific CRIS projects they are associated with. This has cut the size of this report in half.

The information in this Progress Report is organized by Research Unit and a complete Table of Contents is provided on the following pages. For each project described, we have provided a statement of the problem that we are trying to solve, the goals and objectives for this particular research activity, the results obtained during 2001, and our future goals for this research activity for the next three years. We also have included a list of publications along with a contact person if the reader has additional questions or needs more detailed information on a project.

We certainly appreciate your comments and suggestions concerning ways that we can improve this report and we encourage you to continue to send your comments via mail, telephone, FAX, or email to:

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TABLE OF CONTENTS

Biological Research Unit 1
James Throne, Research Leader

CRIS - 5430-43000-018-00D
Monitoring, Prevention, and Control Strategies for Stored-Product Insects..... 2

CRIS - 5430-43000-019-00D
Functional Genomics-Based Management of Stored-Product Insects..... 6

CRIS - 5430-43000-020-00D
Biological Control of Stored-Product Insects 12

CRIS - 5430-43000-021-00D
Decision-Making Tools for Integrated Pest Management of Stored-Product Insects..... 16

Engineering Research Unit 21
Floyd Dowell, Research Leader

CRIS - 5430-43440-003-00D
Improved Handling and Storage Systems for Grain Quality Maintenance and Measurement..... 22

CRIS - 5430-44000-009-00D
Objective Grading and End-Use Property Assessment of Single Kernels and Bulk Grain Samples..... 26

Grain Quality and Structure Research Unit 31
Okkyung Chung, Research Leader

CRIS - 5430-44000-010-00D
Characterization of Grain Biochemical Components Responsible for End-Use Quality..... 32

CRIS - 5430-44000-012-00D
New Uses of Grain Sorghum..... 38

CRIS - 5430-44000-013-00D
Determination and Characterization of Wheat Quality (Hard Winter Wheat Quality Laboratory)..... 41

Plant Science and Entomology Research Unit 47
Robert Bowden, Research Leader

CRIS - 5430-21220-004-00D
Genetic Enhancement of Wheat and Alfalfa for Resistance to Multiple Biotic Stress..... 48

Wind Erosion Research Unit 53
Edward Skidmore, Research Leader

CRIS - 5430-11120-005-00D
Wind Erosion Processes, Assessment, and Control..... 54

Personnel Directory..... 58

BIOLOGICAL RESEARCH UNIT

The mission of the Biological Research Unit is to develop new and improved methods, approaches and strategies for the management of insect pests that attack grain and stored products. In order to decrease the levels of chemical pesticides used to protect our food supply, safer more effective alternatives must be developed. Research Projects include:

CRIS - 5430-43000-018-00D	Monitoring, Prevention, and Control Strategies for Stored-Product Insects
CRIS - 5430-43000-019-00D	Functional Genomics-Based Management of Stored-Product Insect Pests
CRIS - 5430-43000-020-00D	Biological Control of Stored-Product Insects
CRIS - 5430-43000-021-00D	Decision-Making Tools for Integrated Pest Management of Stored-Product Insects

CRIS 5430-43000-018-00D

Monitoring, Prevention, and Control Strategies for Stored-Product Insects

Project Leader: M. Mullen **Investigators:** M. Mullen, F. Arthur, and J. Campbell

Full-Time Scientist Equivalents (SYs): 3.0 **Net Funding to Location per Year:** $ 610,435

Start Date: 10/28/99 **Term Date:** 10/27/04

Problem: Insect pests can contaminate and destroy stored food products which can decrease food quality and destroy customer acceptance. World-wide estimates of product losses due to this pest activity range from 10% to 15% in temperate climates and to more than 30% in sub-tropical and tropical climates. In the U.S., cost estimates for this damage range from 1.2 to 2.4 billion dollars per year.

Effective, economical, and environmentally friendly management of pests in food processing and storage facilities requires the development of new monitoring and control tactics. Monitoring of insect pests in storage and manufacturing facilities will lead to early detection of insect pests so that they can be controlled more easily with fewer chemicals. In addition, information on the distribution of pest populations can allow for more targeted control. Tools such as baited traps and other monitoring techniques need to be developed. Implementation and interpretation of monitoring programs requires an understanding of insect pest behavior. With fewer chemicals available, it also is necessary to identify the factors that can improve the effectiveness of remaining pesticides and to develop new control strategies.

Objectives: The objectives of this project are to develop monitoring and control strategies for stored-product insect pests in and around storage and processing facilities. Included are the development of effective traps baited with chemical attractants, exploitation of insect behavior and ecology to increase the effectiveness of monitoring and control practices, ecologically sound chemical control procedures, non-chemical control methods, and insect-resistant packaging. The physical and biological factors that can affect pesticide efficacy will be determined and new insect growth regulators, inert dusts, and natural products will be examined as alternatives to conventional pesticides. Non-chemical procedures such as the use of aeration for raw grain and heat alone or in combination with diatomaceous earth for processing facilities will be examined for their effectiveness in controlling insect pests.

Results and Impact:

1. Management of Stored-Product Insect Pests in Food Processing Plants and Warehouses. Management of stored-product pests in food processing plants and warehouses continues to rely heavily on calendar-based whole-structure treatments such as fumigation with methyl bromide even though little information is available on the need for, or effectiveness of, these interventions.

Pheromone trap monitoring was used to evaluate the effectiveness of fumigation and the potential causes of pest resurgence after treatment. Fumigations often only provided partial and/or short term suppression of pest populations in the structures and comparison of pheromone trap capture inside and outside of food processing plants suggests that pest immigration into facilities after treatment may contribute to the quick pest resurgence. This information can be used by industry to improve its pest management tactics and can provide baseline data for evaluating the effectiveness of alternative control tactics currently being developed.

2. Understanding Insect Pest Behavior in Food Processing Facilities. Stored-product pests can find and infest spillage in refugia in food processing facilities and from these locations potentially avoid control tactics and initiate new commodity infestations, but the mechanisms involved in this process are not well understood. The ability of the red and confused flour beetles, major pests of flour mills, to utilize multiple small amounts of flour in refugia was investigated. We found that adults visited multiple refugia and that females increased the number of eggs that they laid as the amount of flour in the refugia increased, tending to lay the optimal number of eggs for a given amount of flour. These findings indicate that these beetles have a sophisticated ability to evaluate their patchy environment and maximize the number of offspring produced. This information is helping us improve our understanding of pest population dynamics and distribution in food processing facilities which will ultimately improve our ability to effectively target pest management tactics.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Identify new insecticidal products to control insects in raw commodities and processed food warehouses.

2. Conduct studies of insects and movement patterns inside and outside of food processing facilities.

3. Continue the development and improvement of insect-resistant package designs.

4. Improve our ability to interpret spatial information from insect pest monitoring programs by developing basic knowledge of patch use behavior and response to aggregation pheromones.

5. Assess the potential of biological control agents such as nematodes to control stored product pests inside and outside of facilities.

Specific tasks in 2003 will be to:

1. Conduct field research to verify model simulation studies which support the expanded use of aeration to control insects in stored grain.

2. Continue the evaluation of new insecticidal products designed to control insect pests in raw commodities and processed food warehouses.

3. Conduct laboratory and field studies to improve pheromone-based monitoring systems.

4. Determine the role of odor in insect infestation of processed and packaged foods.

5. Investigate the behavioral interactions between natural enemies and pests and between seed parasites and their hosts.

6. Evaluate the importance of refugia both inside and outside of facilities as sources of infestation and the potential to manage these populations using targeted biological control.

Specific tasks in 2004 will be to:

1. Include combinations of insect growth regulators and diatomaceous earth in insect control studies.

2. Continue to assess the role of aggregation pheromones in the biology of stored-product insects and use this information to improve monitoring and control techniques.

3. Continue cooperative efforts to develop and improve insect-resistant packaging.

Specific Cooperative Agreements for This Project Included:

a. The Department of Entomology, Kansas State University, Manhattan, Kansas

Cooperative Research and Development Agreements for This Project Included:

a. The International Paper Company, Loveland, Ohio

Summary of 2001 Publications/Patents:

01. Arthur, F.H., Throne, J.E., Maier, D.E., Montross, M.D. Impact of aeration on maize weevil (Coleoptera: Curculionidae) populations in corn stored in the Northern United States: Simulation studies. American Entomologist. 2001. v.47. p.104-110.

02. Arthur, F.H. Susceptibility of last-instar red flour beetles and confused flour beetles (Coleoptera: Tenebrionidae) to hydroprene. Journal of Economic Entomology. 2001. v.94. p.772-779.

03. Arthur, F.H., Flinn, P.W. Aeration management for stored hard red winter wheat: simulated impact on rusty grain beetle (Coleoptera: Cucujidae) populations. Journal of Economic Entomology. 2001. v.93. p.1364-1372.

04. Arthur, F.H. Impact of food source on survival of red flour beetles and confused flour beetles (Coleoptera: Tenebrionidae) exposed to diatomaceous earth. Journal of Economic Entomology. 2001. v.93. p.1347-1356.

05. Mullen, M.A., Pederson, J.R. Sanitation and Exclusion. Alternatives to pesticides in Stored-product IPM. Subramanyam, B., Hagstrum, D.W., editors. Kluwer Academic Publishers, Boston, MA. 2000. p.29-50.

06. Mullen, M.A., Dowdy, A.K. A pheromone-baited trap for monitoring the Indianmeal moth, Plodia interpunctella (Hubner) (Lepidoptera: Pyralidae). Journal of Stored Product Research. 2001. v.37. p.231-235.

07. Pitts, J.T., Arthur, F.H. Grains and Protectants. Francis, F.J., editor. E.J. Wiley and Sons, Inc. Wiley Encyclopedia of Food and Technology, Second Edition. 2000. p.1212-1276.

08. Reed, C., Arthur, F.H. Aeration. Alternatives to pesticides in stored-product IPM. Subramanyam, B., Hagstrum, D.W., editors. Kluwer Academic Publishers, Boston, MA. 2000. p.51-72.

09. Zettler, J.L., Arthur, F.H. Chemical control of stored product insects with fumigants and residual treatments. Crop Protection. 2000. v.19. p. 577-582.

For More Information on this Project Contact:

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CRIS 5430-43000-019-00D

Functional Genomics-Based Management of Stored-Product Insect Pests

Project Leader: K. Kramer **Investigators:** K. Kramer, R. Beeman, and J. Baker

Full-Time Scientist Equivalents (SYs): 3.0 **Net Funding to Location per Year:** $ 728,145

Start Date: 10/27/99 **Term Date:** 10/26/04

Problem: Stored-product insects cause numerous problems throughout grain production and marketing channels, which relate to the conservation, production, harvesting, storage, marketing, and utilization of wheat, sorghum, corn, rice, barley, oats, soybeans, and triticale. These pests are detrimental to commodity nutritional value, consumer acceptance, and end-use performance. As value is added to these commodities, losses become even more significant. Because export markets depend on high quality products, any reduction in grain quality will result in loss of economic benefits to the American farmer and processor. Novel pest management practices are needed to prevent spoilage or contamination by post-harvest pests and pathogens and to conserve resources and maintain overall commodity quality during handling, conditioning, storage, and processing.

Objectives: The goal of this project is to develop ecologically-sound pest management technologies to replace or reduce the use of traditional pesticides. Novel control techniques that offer an alternative to environmentally hazardous chemical insecticides and that can significantly reduce these commodity losses during storage are being developed based on a knowledge of insect genetics, physiology, biochemistry, toxicology, and molecular biology. Specifically, we are characterizing the physiological and genetic processes in stored-product insects which can be manipulated in order to develop control tactics using biopesticides and natural enemies. We also are developing techniques for genetic manipulation of insects and devising methods for managing pesticide resistance and enhancing the effectiveness of beneficial insects. In addition, we are developing the techniques to increase the expression and activity of biopesticides in transgenic plants.

Results and Impact:

1. Maternal Larvicidal Gene Identified. In 2001, we identified the novel maternal, larvicidal gene Medea-1 as a member of the sodium-neurotransmitter symporter family. This class of genes is responsible for the production of proteins that stop the actions of neurotransmitters (chemicals that carry nerve impulses from one nerve cell to another) such as serotonin, noradrenaline, and gamma-aminobutyric acid by active reuptake of these compounds. Such reuptake pumps have been implicated in many common mood disorders in humans, and are the targets of many drugs and pharmaceuticals. Sodium neurotransmitter symporters represent a novel class of inhibitor targets for insect pest control applications because they can be used to disrupt normal nerve functions in insect pests.

2. History of Grain-Protecting Biopesticide Development Reported. The history of the development of the antivitamin protein avidin as a biopesticide and its relevance as a value-added crop commodity were described. The initial objective was to find a human food protein that could be used as an insecticide. Avidin corn was first generated, however, for the production of avidin that was used in other types of applications such as in medical diagnostic test kits. This commercialization was followed by studies demonstrating that the avidin present in transgenic corn was a very effective grain-protecting biopesticide. This proved that the concept of incorporating naturally occurring biopesticides into grain is an effective method for insect pest control.

3. New Forms of Insecticidal Protein Developed. In prior research, we showed that an insect molting enzyme, chitinase, acts as a biopesticide in transgenic plants where it disrupts gut physiology. However, instead of a single protein, several modified forms were unexpectedly found in the tissues of the transgenic plants. Together with scientists at Kansas State University and Kinki University in Japan, we conducted gene deletion and structure-function experiments to help identify and characterize several of the multiple forms of the biopesticidal protein. The data revealed how a full-length protein is processed at one end to generate smaller forms that are still enzymatically active. The results obtained provided useful information about biopesticide gene expression in plants and also structure-activity relationships. The findings may facilitate a more effective application of the insect chitinase gene for the control of insect pests. The long-term goal of this research is to improve the properties of this biopesticide, including enzymatic activity, stability, and insecticidal activity.

4. Indianmeal Moth Blood Contains Proteins That Supply Essential Amino Acids During Metamorphosis and Reproduction. The Indianmeal moth (IMM) is a stored grain insect that causes extensive damage to cereals and their milled products. For insects like the IMM, protein reserves must be accumulated to support needed biological functions during stages of development where feeding does not occur. Understanding the biochemical mechanisms responsible for the growth of IMM larvae, pupae, and adults will facilitate the identification of potential physiological targets for insect control agents such as insect growth regulators and biopesticides. We investigated IMM blood proteins that are produced at critical periods of development. Two highly abundant proteins were identified, which supply essential amino acids during metamorphosis and reproduction. The genes for these proteins, which are called hexamerins because they exist as large hexameric aggregates under physiological conditions, were isolated, characterized, and compared with related genes from other species of insects. Our results provided a greater understanding of how nutritional storage reserves are developed in the IMM and similar insect pests. This information will be used to develop biotechnological methods of insect pest control that disrupt normal insect development.

5. Zinc and Manganese in Insect Teeth Are Important Minerals for Development and Infestation of Grain. Insect mandibles (teeth) are used to damage and penetrate intact grain kernels. We have examined whether the ability of insect pests to attack kernels may be influenced by the presence of metals in the mandibular teeth. In a collaborative study with scientists in the UK, we showed for the first time that not only adult but also larval mandibles of several stored

product insect pests have high levels of zinc and/or manganese. Larvae that do not have such high levels of metals in their mandibles are less capable of penetrating whole kernels. The data demonstrated that metals affect the hardness of insect mandibles, which in turn enhances the ability of stored-product insects to attack whole grain. This information could be useful for the development of pest control methods that diminish the ability of pests to deposit metals in their mandibles.

6. Gene Important for Insect Development Cloned. The cDNA containing the code for a very important enzyme in insect developmental biology, chitin synthase (CHS), was isolated and characterized. Chitin is the structural polysaccharide found in the exoskeleton and gut, and CHS controls its synthesis. In the past, CHS has been the target of insect growth regulators, but it has been very difficult to study because of its very large size and localization in the cellular plasma membrane. Obtaining the cloned cDNA is a significant step that will allow development of reagents for use in future research on the expression, properties and regulation of CHS, as well as for the development of chitin synthesis inhibitors. Together with scientists at Kansas State University and Boston University, we analyzed and described the nucleotide and amino acid sequences, and made comparisons with similar enzymes from other organisms, including nematodes and fungi. The insect enzyme is expressed in the epidermis and apparently functions to make chitin that is deposited in the exoskeleton. The results obtained provided new information about structure-activity relationships, and added to the knowledge base for biosynthetic enzymes and insect molecular science. The long-term goal of this research is to develop more effective ways to use inhibitors of chitin synthase to control insect pests.

7. Ovarian Physiology Used to Age-grade Weevils. Physiological changes in the ovarian (egg production) system in rice weevils were used to determine the age of these major insect pests of stored cereals. A layer of cells, called the follicular epithelium, surrounds the developing oocyte within the ovaries of reproductive females. This cellular epithelium is sloughed off during oviposition. The degree of accumulation of these follicular "relics" can be used to estimate the number of eggs laid and, correspondingly, the age of the weevil. Knowing the age of female weevils can be used to characterize the age structure and growth dynamics of the insect population in a given grain storage facility and this information can be exploited to apply the most appropriate control tactics.

8. cDNA for Recognition Protein Cloned from Indianmeal Moth Expression Library. A near full-length cDNA that contains the code for a β-glucan recognition protein (β-GRP) from the Indianmeal moth was obtained from an expression library by using an antibody to the tobacco hornworm β-GRP as a probe. This protein is an important component of the insect immune system that is responsible for recognizing foreign invaders. The intact β-GRP and the N-terminal region of the protein causes yeast and bacterial cells to aggregate or clump together. The C-terminal region of the protein did not cause aggregation of these microorganisms. The intact β-GRP also activates the prophenoloxidase cascade, a major component of the Indianmeal moth's immune response system. The open reading frame of the full length cDNA encodes 488 amino acids and the molecular mass of the mature protein is 53,311 Daltons. The protein is produced by

all insect life stages (eggs, larvae, pupae, and adults). The long range goal of this research is to develop novel control methods by manipulating the insect's immune response system.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Determine three-dimensional structure of the unique N-terminal domain of the Indianmeal moth β-GRP recognition protein by spectroscopic analysis in cooperation with KSU.

2. Test several new gene tagging and gene transfer vectors and characterize genes required for molting.

3. Continue studies to identify cuticle cross-linking and molting agents and also determine how substrates and enzymes harden and degrade the exoskeleton of insects.

4. Continue studying the biological and biochemical activities of the β-GRP recognition protein and it's interaction with microorganisms.

5. Clone and characterize additional genes, including prophenoloxidase and peptidoglycan recognition protein, that are part of the Indianmeal moth's immune system.

Specific tasks in 2003 will be to:

1. Complete new, higher-resolution molecular maps and gene expression libraries of the red flour beetle genome, and develop strategies that will begin to catalog new genes that represent likely targets for pest control intervention.

2. Continue characterizing genes for digestive and molting enzymes and also evaluating potential insect control proteins that inhibit digestive and molting physiology.

3. Continue studies on the mechanisms of activation of the prophenoloxidase system via recognition molecules.

4. Determine the possible role of immunosuppressants produced by an ectoparasitic wasp that parasitizes Indianmeal moth larvae.

5. Analyze functional changes in the immune system when Indianmeal moth larvae are under parasitoid attack.

Specific tasks in 2004 will be to:

1. Develop reliable and routine systems for genetic manipulation of pest insects and their target genes.

2. Determine the effectiveness of cuticle inhibitors on the growth and development of stored-product insects.

3. Develop transgenic plants that incorporate insect control proteins as resistance factors.

4. Continue unraveling the complex nature of the immune response in the Indianmeal moth and other stored product insects.

Specific Cooperative Agreements for This Project Included:

a. The Departments of Biochemistry, Biology, and Entomology at Kansas State University, Manhattan, Kansas
b. The Human Frontier Science Program, Headquarters in France

Cooperative Research and Development Agreements for This Project Included:

a. Exelixis Pharmaceuticals, San Francisco, California

Summary of 2001 Publications/Patents:

01. Baker, J.E., Fabrick, J.A. Host hemolymph proteins and protein digestion in larval Habrobracon hebetor (Hymenoptera: Braconidae). Insect Biochemistry and Molecular Biology. 2000. v.30. p.937-946.

02. Beermann, A., Jay, D.G., Beeman, R.W., Hulskamp, M., Tautz, D., Jurgens, G. The short antennae gene of Tribolium is required for limb development and encodes the ortholog of the Drosophila Distal-less protein. Development. 2001. v.128. p.287-97.

03. Dowell, F.E., Broce, A.B., Xie, F., Throne, J.E., Baker, J.E. Detection of parasitised fly puparia using near infrared spectroscopy. Journal of Near Infrared Spectroscopy. 2000. v.8. p.259-265.

04. Haas, M.S., Brown, S.J., Beeman, R.W. Homeotic evidence for the appendicular origin of the labrum in Tribolium castaneum. Development, Genes and Evolution. 2001. v.211. p.96-102.

05. Haas, M.S., Brown, S.J., Beeman, R.W. Pondering the procephalon: the segmental origin of the labrum. Development, Genes and Evolution. 2001. v.211. p.89-95.

06. Kramer, K.J., Kanost, M.R., Hopkins, T.L., Jiang, H., Zhu, Y.C., Xu, R., Kerwin, J.L., Turecek, F. Oxidative conjugation of catechols with proteins in insect skeletal systems. Tetrahedron. 2001. v.57. p.385-392.

07. Zhu, Y.C., Kramer, K.J., Dowdy, A.K., Baker, J.E. Trypsinogen-like cDNAs and quantitative analysis of mRNA levels from the Indianmeal moth, Plodia interpunctella. Insect Biochemistry and Molecular Biology. 2000. v.30. p. 1027-1035.

For More Information on this Project Contact:

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CRIS 5430-43000-020-00D

Biological Control of Stored-Product Insects

Project Leader: R. Howard **Investigators:** R. Howard, B. Oppert, and J. Lord

Full-Time Scientist Equivalents (SYs): 3.0 **Net Funding to Location per Year:** $ 625,937

Start Date: 10/27/99 **Term Date:** 10/26/04

Problem: Economic losses of post-harvest food and fiber due to damage caused by storage insect pests cost U.S. consumers and producers billions of dollars every year. Traditional chemical control methods for insect pests that attack stored grain and commodities are rapidly being lost because insects are developing resistance to insecticides, general public awareness of environmental and food safety concerns is increasing, and more stringent regulatory restrictions are being placed on the use of insecticides. The development of economically sound, environmentally-safe biocontrol agents for storage insect pests is urgently needed. Biological control agents have more complex interactions with pest species than conventional pesticides and fumigants. Successful implementation of biological control will require a better understanding of the biology of the pests as well as their natural enemies. The practical development of such agents is hindered by inadequate knowledge of the biology and biochemistry of the agents. We need to understand how pests respond and adapt to biocontrol agents.

Objectives: The long term goals of this project are to develop economically viable biological, genetic, and integrated control methods for stored product pests that are compatible with the environment and with conservation of natural resources.

Results and Impact:

1. Determine the Impact of Biological Insect Control Methods on Beneficial Insects. A major concern in the use of insect pathogens to control pest species is the potential for negative effects on non-target species, especially beneficial insects that themselves contribute to pest control. We tested the interactions of an important parasitoid wasp and its beetle host with a fungus that is used to control some beetle species and found a potential negative impact of the fungus on the parasitoid. This parasitoid does not encounter this fungus under most natural conditions, and hence has not evolved avoidance behaviors. This beetle-fungus-parasitoid study has revealed problems associated with mixed biological control strategies, and further studies will be required to overcome them.

2. Evaluation of the Effectiveness of Biological Pest control Methods on the Red Flour Beetle. The red flour beetle is the most difficult pest to control in grain processing areas. We have tested a fungal insecticide/desiccant dust combination on larvae and adults of this species. Although the adult beetles are virtually impervious to the combination, the larvae are killed by

moderate doses. This finding creates the potential for development of a safe and environmentally friendly approach to a difficult pest management problem.

3. Development of Digestion Inhibitors as an Insect Pest Control Method for Beetles. The digestive enzymes of five stored-product beetle pests were characterized. Compounds that can inhibit or stop the normal activities of these digestive enzymes may be very effective insect control agents. While some stored product beetles have similar digestive systems, many have unique digestive enzymes and will require a multiple inhibitor approach for effective control. Identification of biopesticides, such as digestive enzyme inhibitors, will provide more effective and efficient control of stored product pests.

4. Recognition Methods Include Surface Chemicals. Better biological control technologies using parasitic wasps are needed for stored product insect pests, and an important problem is to determine how wasps find and recognize each other and produce offspring. Surface chemicals, known as cuticular hydrocarbons, on two parasitic wasps and their hosts were identified. These chemicals function as species and gender recognition cues and were shown not to vary, even when the wasp was reared on different hosts. Such information will be useful in designing studies to manipulate the wasp's behavior to maximize the amount of time they spend in the stored product commodity mating and searching for stored product pests to kill.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Continue to develop a better understanding of the behavioral and chemical mechanisms used by storage pests and by their natural enemies and how natural enemies locate pest insect species and find mates. We will also examine chemical and behavioral interactions among different natural enemies that attack stored product insects.

2. Continue to evaluate insecticidal proteins identified by insect digestive physiology studies and study insect digestive enzymes using molecular biology techniques.

3. Continue to evaluate new compounds and pathogens, especially insect specific protozoans, for the development of pest insect control methods, and develop improved production systems for insect pathogens.

Specific tasks in 2003 will be to:

1. Develop a better understanding of the interactions among the guild of natural enemies that attack stored product insects and to chemically characterize important semiochemicals used by the parasitoids and their hosts.

2. Use information gained in 2002 to identify processes that are involved in the regulation of stored product insect digestion.

3. Develop a simulation model for the impact of a broad-host-range pathogen on populations of stored-grain pests and identify effective combinations of insect pathogens with other agents for control of stored-grain insects.

4. Initiate studies to achieve a better understanding of the biology and natural pest control impact of a protozoan disease of stored grain beetles and determine the potential for control of stored product beetles by introduction of protozoan pathogens.

Specific tasks in 2004 will be to:

1. Develop ways to use parasitoid and host semiochemicals in Integrated Pest Management control of stored product insects.

2. Identify new, novel macromolecular biopesticides that regulate insect digestive enzymes to control stored product insects.

3. Describe mechanisms for the modulation of host immune responses to insect pathogens and determine the effectiveness of combinations of fungi in controlling stored-product insect pests.

Summary of 2001 Publications/Patents:

01. Herrero, S., Oppert, B., Ferre, J. Different mechanisms of resistance to Bacillus thuringiensis in the Indianmeal moth. Applied Environmental Microbiology. 2001. v.67(3). p.1085-1089.

02. Howard, R.W. Cuticular hydrocarbons of adult Pteromalus cerealellae (Hymenoptera: Pteromalidae) and two larval hosts, Angoumois grain moth (Lepidoptera: Gelechiidae) and cowpea weevil (Coleoptera: Bruchidae). Annals Entomological Society of America. 2001. v.94(1). p.152-158.

03. Lord, J.C. Advancements and successes in microbial control with fungi. International Congress of Entomology. 2000. Abstract p. 502.

04. Lord, J.C. Ultrastructure and development of a Mattesia in the rusty grain beetle Cryptolestes ferrugineus. 2000. Entomological Society of America. Paper No. D0458.

05. Lord, J.C. Desiccant dusts synergize the effect of Beauveria bassiana (Hyphomycetes: Moniliales) on stored grain beetles. Journal of Economic Entomology. 2001. v.94(2). p.367-372.

06. Lord, J.C. Response of the wasp Cephalonomia tarsalis (Hymenoptera: Bethylidae) to Beauveria bassiana (Hyphomycetes: Moniales) as free conidia or infection in its host, the

sawtoothed grain beetle, Oryzaephilus surinamensis (Coleoptera: Silvanidae). Biological Control. 2001. v.21(3). p.300-304.

07. Moore, D., Lord, J.C., Smith, S. Pathogens. Subramanyan, Bh., Hagstrum, D.W., editors. Kluwer Academic Publishers, Dortrecht. Alternatives to Pesticides in Stored-Product IPM. 2000. p.193-227.

08. Oppert, B. Targeting digestion in stored product pests. 2000. Entomological Society of America. Paper No. 0795.

09. Oppert, B. Transgenic plants expressing enzyme inhibitors and the prospects for biopesticide development. Koul, O., Dhaliwal, G.S., editors. Harwood Academic Publishers, The Netherlands. Phytochemical Biopesticides. 2000. p.83-95.

10. Oppert, B., Hartzer, K., Smith, C.M. Characterization of the digestive proteinases of Hypera postica (Gyllenhal) (Coleoptera: Curculionidae). Transactions Kansas Academy of Science. 2000. v.103(3-4). p.99-110.

11. Oppert, B., Hammel, R.A., Throne, J.E., Kramer, K.J. Fitness costs of resistance to Bacillus thuringiensis in the Indianmeal moth, Plodia interpunctella (Lepidoptera: Pyralidae). Entomologia Experimentalis Applicata. 2000. v.96(3). p.281-287.

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CRIS 5430-43000-021-00D

Decision-Making Tools for Integrated Pest Management of Stored-Product Insects

Project Leader: P. Flinn **Investigators:** P. Flinn, and J. Throne

Full-Time Scientist Equivalents (SYs): 2.0 **Net Funding to Location per Year:** $ 681,361

Start Date: 10/27/99 **Term Date:** 10/26/04

Problem: Insects cause major reductions in the quality of stored grain and other stored products in the U.S. and around the world. This is a very serious problem because each year it is estimated that losses due to insects in stored grain are 5% to10% in developed countries and up to 30% in developing countries. In the U.S., this amounts to losses ranging from 1.2 to 2.4 billion dollars per year. New regulations are increasing the cost and difficulty of using pesticides, and insects are becoming resistant to pesticides. More cost-effective pest management programs are urgently needed to maintain the quality of the food supply in the U.S. and our competitiveness in global markets.

Objectives: The primary objective of this project is to develop integrated pest management (IPM) programs for stored grain and stored-product insects. This will be accomplished by developing better insect monitoring methods, increasing our knowledge of stored-product insect ecology, and by developing accurate insect population growth models and decision support tools. Specifically, we will provide the technology to detect insect infestations more accurately and earlier. We will develop decision support tools that predict the effects of different control actions such as cooling, heat, biological control, protectants, or fumigants, and provide treatment recommendations.

Results and Impact:

1. Development of Area-Wide Integrated Pest Management Strategies for Implementation.

Area-wide IPM programs were developed for implementation in elevator networks in Kansas and Oklahoma in collaboration with Kansas State and Oklahoma State Universities. We demonstrated that sampling grain for insects using a vacuum-probe provided an accurate and economical method for estimating insect density in concrete elevators; we also developed risk-analysis software that uses sampling estimates and an insect-growth model to predict which bins should be fumigated. This research will make area-wide integrated pest management programs available to grain elevators and thus, decrease the number of unnecessary fumigations, reduce insect-damaged grain, and help maintain the competitiveness of United States grain in global markets.

2. Development of a Population Growth Model for Stored-Grain Insect Pests in Concrete Silos. We developed a population growth model for stored grain insects in concrete silos. Data from elevators in Kansas and Oklahoma was used to validate the model, and it predicted insect distribution and insect density accurately. This model will be used in a risk-analysis system for elevator grain storage and should reduce the frequency at which grain needs to be sampled, thus, reducing the cost of area-wide IPM.

3. Detection of Insect Fragments Using NIRS. The presence of insect fragments in commercial wheat flour is a major concern to the milling industry because consumers expect high quality and wholesome products at the retail level. We tested a rapid, near-infrared spectroscopy (NIRS) method for detecting insect fragments in flour, and compared the sensitivity and accuracy of the NIRS method with that of the current standard flotation method. We were unable to predict whether or not the number of fragments in a sample exceeded the action level of 75 fragments in 50 grams of flour; however, we were able to predict accurately whether flour samples contained less than or more than 130 fragments in 50 grams of flour. Although current NIRS instruments are unable to detect insect fragments at the action level, this method should be reexamined in the future because NIRS technology is rapidly improving.

Goals for 2002, 2003, and 2004:

Specific Tasks in 2002 will be to:

1. Test a practical insect sampling and risk-analysis software program that will provide advice to elevator managers. The program will indicate high-risk bins that need attention. We will provide the elevator managers with this information every two months and compare their management actions with the actions recommended by the risk- analysis software. This IPM program will be implemented in two elevator networks in Kansas and Oklahoma. Models will be developed that predict insect population growth in mills and warehouses.

2. Continue the development of automated monitoring systems for insects in grain. These systems could be used in elevator storage to continuously monitor grain for insects.

3. Complete the study examining the use of NIRS for chronological age-grading of long-lived stored-grain insect pests and compare this method with alternative methods such as measuring yellow body formation and the process of cell destruction through the study of caspases (cysteine-requiring aspartate proteases), which are a family of enzymes that cause cell death.

4. Conduct studies investigating the effectiveness of releasing beneficial insects in mills to suppress insect pests. Combining heat treatments of facilities with biological control may provide an alternative to methyl bromide fumigation.

Specific Tasks in 2003 will be to:

1. Continue testing and refining the risk-analysis software. Elevators outside our elevator network will be encouraged to adopt this area-wide IPM program. A final version of the insect risk-analysis software for commercial elevators will be released to the public.

2. Develop a decision support system for insect management in flour mills and warehouses.

3. Continue to test the effectiveness of biological control for suppressing insects in flour mills.

Specific Tasks in 2004 will be to:

1. Test and validate the decision support software for insect management in flour mills and warehouses.

Specific Cooperative Agreements for This Project Included:

a. The Department of Entomology, Montana State University, Bozeman, Montana
b. The Department of Electrical and Computer Engineering, Kansas State University, Manhattan, Kansas
c. The Department of Entomology, Oklahoma State University, Stillwater, Oklahoma
d. The Department of Grain Science and Industry, Kansas state University, Manhattan, Kansas

Summary of 2001 Publications/Patents:

01. Flinn, P.W., Hagstrum, D.W. Augmentative releases of parasitoid wasps in stored wheat reduces insect fragments in flour. Journal of Stored Products Research. 2001. v.37. p.179-186.

02. Perez-Mendoza, J., Fabrick, J.A., Zhu, K.Y., Baker, J.E. Alterations in esterases are associated with malathion resistance in Habrobracon hebetor (Hymenoptera: Braconidae). Journal of Economic Entomology. 2000. v.93(1). p.31-37.

03. Scholler, M., Flinn, P. W. Parasitoids and Predators. Subramanyam, Bh., Hagstrum, D.W., editors. Kluwer Academic Publishers, Boston, MA. Alternatives to Pesticides in Stored-Product IPM. Chapter 9. 2000. p.229-271.

04. Throne, J.E., Baker, J.E., Messina, F.J., Kramer, K.J., Howard. J.A. Varietal resistance. Subramanyam, Bh., Hagstrum, D.W., editors. Kluwer Academic Publishers, Boston, MA. Alternatives to pesticides in stored-product IPM. 2000. p.165-192.

05. Throne, J.E., Parajulee, M.N., Phillips, T.W. Computer model for simulating population dynamics of the predator Lyctocoris campestris (Heteroptera: Anthocoridae) in stored shelled corn. Environmental Entomology. 2000. v. 29. p.1236-1243.

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ENGINEERING RESEARCH UNIT

The mission of the Engineering Research Unit is to: (1) develop technologies to improve grain quality assessment, handling, and storage through innovative engineering research; (2) transfer knowledge and technology that meet the needs of consumers and the grain industry; (3) provide engineering expertise through cooperative research with other laboratories, agencies, universities, and industry groups; and (4) maintain an environment that fosters teamwork, innovation, and personal growth. Specific projects for this Unit include:

CRIS - 5430-43440-004-00D	Improved Handling and Storage Systems for Grain Quality Maintenance and Measurement
CRIS - 5430-44000-009-00D	Objective Grading and End-Use Property Assessment of Single Kernels and Bulk Grain Samples

CRIS 5430-43440-004-00D

Improved Handling and Storage Systems for Grain Quality Maintenance and Measurement

Project Leader: M. Casada **Investigators:** M. Casada and Vacant

Full-Time Scientist Equivalents (SYs): 1.6 **Net Funding to Location per Year:** $ 444,690

Start Date: 05/13/01 **Term Date:** 08/31/02

Problem: The production and marketing of grain is a major component of the U.S. agricultural economy, food production, and export trade. Improved grain drying, storing, aerating, and handling while maintaining quality and energy efficiencies will increase food wholesomeness, safety, and market competitiveness. This information is useful to producers, elevator and dryer operators, equipment and facility design engineers, marketers and handlers of grain, Extension Service specialists, and government regulatory agencies. This research can also significantly improve worker safety by reducing elevator explosions caused by grain dust.

Objectives: An important goal of this project is the development of post-harvest engineering technology for grain quality assessment, maintenance, and functional utilization with emphasis on energy conservation and personnel safety. Specific areas include the improvement of grain aeration management and practices, evaluation of water mist in controlling grain dust emissions, development of economical and compliant methods for control of grain dump pit dust emissions, validation of current procedures for predicting allowable storage times under changing temperature and moisture conditions, development of a chemical-free method of pre-filling sanitation of grain storage bins, and development of more energy efficient methods for artificially drying shelled corn and other commodities. This research supports the national need for grain facility and worker safety where fires and explosions as a result of ineffective grain dust control and management continue to occur and where agricultural workers are frequently exposed to environments at high respiratory dust levels. Compliance and standards for atmospheric grain dust emissions from grain handling facilities are also addressed. The objectives of this project are to address these issues through the development of new procedures and methods, the application of new technologies, and the performance of tests in GMPRC's pilot grain elevator and other grain handling facilities.

Results and Impact:

1. Identity Preserved Grain Handling in Grain Elevators. This is cooperative work with Kansas State University designed to evaluate the co-mingling of different grains during elevator handling and establish procedures to facilitate value-added and identity preserved grain segregation operations. In tests of incoming corn handling at the GMPRC elevator, total residual grain in the elevator boot and pit combined was 300 lb. Of this total, about 10% was fines and dust, 10 to 15% was broken kernels, and the remainder was whole kernels. The co-mingling tests

indicated that only the first 15 to 20 bu of grain (approximately 1% of the leg rate per hour, which was approximately 2000 bu/h in these tests) were contaminated at greater than a 1% level; only the first 40 to 50 bu of grain (approximately 2% of the leg rate per hour) were contaminated at greater than a 0.5 % level. Future tests will correlate these results to larger commercial elevator operations. This information is needed by elevator operators to better segregate grain with desirable characteristics into separate channels for delivery to end-users. The information is also useful to grain processors for improving their handling of specialty grains.

2. Evaluation of a Pre-filling Bin Sanitation Method Using Heat. A chemical-free method of pre-filling sanitation of grain storage bins is needed since even a chemical-free aeration storage plan still needs pesticides to properly sanitize bins prior to storage. We evaluated the benefits of heat treatment for sanitation before filling bins in a ca. 5000 bu bin outfitted with a full perforated floor and 18 kW electric heater for low-temperature drying, which provided an adequate heat source for the heat treatment. Results showed that supplemental distribution fans are required to get reasonably uniform heat distribution under the perforated floor, with the best configuration to date being to cover the perforated floor with a tarp and deliver the heat under the perforated floor, uniformly distributed around the entire perimeter of the bin. This new treatment method has the potential to reduce or eliminate the need for pesticides during sanitation of bins before filling. Economics have yet to be determined, but this technology will reduce the level of pesticides applied to wheat destined for food use.

3. Evaluation of Temperature Management Strategies to Reduce Pesticide Usage. When newly harvested wheat is placed in storage during the summer in warm climates without residual pesticides, high temperatures promote the development of stored grain insects for several weeks before early autumn aeration cycles are started, even though night temperatures often are low enough to limit population development of insect pests. Field validation tests are underway to evaluate three temperature management strategies to reduce pesticide usage -- including one with controlled aeration at 23.7 deg. C (75 deg. F) immediately after binning, in addition to the usual autumn cooling cycles -- along with a simplified, economical temperature monitoring system. During the first year, the summer aeration cycle was effective at reducing temperatures to a level that slows insect development (21 - 24 deg. C), although some locations in the bin subsequently re-warmed to levels near optimum for insect growth and reproduction without maintenance aeration cycles to sustain the lower temperatures. Results from this project may lead to the development of new insect pest management and temperature management strategies for stored wheat, benefitting grain producers and the entire U.S. wheat industry by producing cleaner grain and safer food for both domestic and export uses.

4. Dust Control in an Elevator Facility Using Water Mist. Water spray/mist may be an effective and economical method to control grain dust emissions, but the effectiveness and system design procedures to control emissions are unknown. Dust emissions from corn and wheat lots and the spray/mist were further characterized with a phase-Doppler particle analyzer. A 50-bushel grain-drop test was prepared for measuring the airflow in a test chamber that is 2.5 ft x 6 ft x 8 ft, which represents a portion of a receiving hopper. Measurements showed that at 3" from the nozzle tip, the average drop size was 25 um and the average velocity was

20 meters/second (m/s), while at 12 inches, drop velocity had decreased to 6 m/s -- which was similar to the air velocity -- and larger drops were falling out the bottom of the plume. This work should maximize the effectiveness of dust control in grain handling environments to reduce explosion disasters such as the 135 reported grain dust explosions in a recent ten year period (1989 - 1998) that killed 17 people, injured 129, and caused $100 million of facility damage. This research should also facilitate acceptance of misting technology and alleviate industry concerns associated with wetting grain.

5. Development of Components for a U.S. Grain Bin Sealing Standard. For decades, U.S. grain elevators have experienced fumigation failures in steel bins due to inadequate sealing of bins and controlled atmospheres used for insect control typically fail due to the same sealing problems. Standard steel bin designs were evaluated to determine needed component design changes to achieve adequate sealing for fumigation and controlled atmosphere applications. Grain bins should be designed with base and sidewalls that can be sealed; roofs that exclude insects and allow movement of fresh air through the headspace; and with roof vents, hatches, and doors that can be quickly sealed during bin treatments. This work has identified the key components needed for a U.S. bin sealing standard, which will give manufacturers the guidance they need to design bins with adequate sealing for fumigation and controlled atmosphere grain storage, resulting in improved stored grain quality and cleanliness.

6. Pre-filling Heat Treatment of On-Farm Grain Storage Bins. Our indoor bin (ca. 5000 bu) was outfitted with an 18 kW electric heater. This would normally be used for low-temperature drying, but also provides an adequate heat source for the heat treatment. Traps were used to monitor insects at approximately 10 locations both before and after heat treatment. The heat source is arranged to simulate use of a grain dryer to supply heat from a single inlet to the plenum under the full perforated drying floor—a reduced airflow compared to the typical drying fan must be used to avoid excess exhaust heat losses. Testing showed that more distribution fans are needed to obtain reasonably uniform heat distribution under the perforated floor. This method has the potential to reduce or eliminate the need for pesticides during the sanitation of bins before filling.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Measure the residual amount of grain left in each piece of equipment in the elevator after loading and unloading transfers have been completed, and the amount of contamination from those residual amounts present in the next grain lot passing through the system.

2. Investigate other heat sources for the pre-filling heat treatment of grain storage bins and heating methods for the best insect control will be optimized. Additional methods of air distribution to improve the uniformity of heating and efficacy of the heat treatment will be evaluated.

3. Evaluate the ability of high-speed sorters to detect and remove defects (wrong color class and insect infested kernels) in wheat and corn.

4. Conduct air/dust/spray validation tests to confirm the mathematical models and provide fundamental data on the effectiveness of sprays to control dust.

Specific tasks in 2003 will be to:

1. Measure dust emission and particle size distribution during grain unloading at the GMPRC elevator as affected by type of grain, moisture content, grain quality, grain flow rate and drop height and quantify air entrainment during grain unloading as affected by the type of grain, moisture content, grain quality, grain flow rate and drop height

Specific tasks in 2004 will be to:

1. Continue to analyze and evaluate the performances of selected grain aeration strategies. The data will be used to validate the grain storage computer model. The effectiveness and time requirements of short maintenance aeration cycles in the summer and fall will be evaluated.

Summary of 2001 Publications/Patents:

Nothing to report at this time.

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CRIS 5430-44000-009-00D

Objective Grading and End-Use Property Assessment of Single Kernels and Bulk Grain Samples

Project Leader: T. Pearson **Investigators:** T. Pearson and F. Dowell

Full-Time Scientist Equivalents (SYs): 2.4 **Net Funding to Location per Year:** $ 713,099

Start Date: 02/01/97 **Term Date:** 01/31/02

Problem: The production and marketing of grain are major components of the U.S. agricultural economy, food production, and export trade. Improved utilization and market efficiencies with objective quality, functionality and grain grade assessments will increase food wholesomeness, safety, and market competitiveness. For example, accurate, rapid detection of attributes could assist in marketing or segregating genetically modified organisms or detecting food safety concerns. This information is particularly useful in evaluating grain prior to purchase or trade in market channels. Single kernel assessments are needed to detect defects that may be present in only a small percentage of kernels or to detect mixtures of contrasting quality characteristics. New technology developed through this research will provide the Federal Grain Inspection Service (FGIS) with several options for providing additional objective quality assessments of grain along with official grade services and thereby improve their services and operating efficiencies. These objective assessments of grain quality are useful to producers, breeders, growers, grain handlers, marketers, millers, bakers, and government agencies such as the Extension Service, FGIS, FSIS, APHIS and OSHA. Accurate detection of genetically modified grain and accurate measurement of other grain quality attributes will help preserve our export markets, which contribute over one billion dollars to the US economy.

Objectives: The main goal of this research is to develop sensors and instrumentation for objective grading, on-line measurement, and end-use property assessment of single kernels or bulk grain samples. Specific issues being addressed include: rapid assessment of physical properties such as kernel size; near-infrared (NIR) measurements of single kernel attributes such as fungal damage or internal insects; machine vision assessment of bread crumb grain; objective detection of wheat kernel defects in FGIS Line Slide images; objective analysis of dough mixing; methodology to relate physical properties of wheat to milling energy and optimum mill settings; quality oriented marketing of hard winter wheat; and use of single kernel characterization system (SKCS) data for commercial milling of SRW, SWH and HRS wheat.

Results and Impact:

1. The Use of Optical Sensors to Detect Karnal Bunt in Wheat. The presence of Karnal bunt has resulted in thousands of acres and millions of bushels of wheat being quarantined in the US in 2001. This disease is a threat to all US wheat production, and could devastate our export wheat markets and US agriculture economy. In 1997, we demonstrated that we could detect bunted

kernels using optical sensors. As a result, we cooperated with the USDA-Animal and Plant Health Inspection Service (APHIS), several state labs, and Satake USA to apply high-speed sorting technology to rapidly screen samples for the presence of bunted kernels. We showed that this technology can remove 100% of bunted kernels from samples, which will reduce inspector error and significantly reduce sample processing time. These results have changed the procedure for inspecting samples for bunted kernels, and the reduction in errors and time will greatly improve our ability to detect and control additional outbreaks, and help insure the quality of our grain and preserve our export markets.

2. Development of a Low-Cost, Single Kernel Quality Measurement Device. We developed a low-cost single kernel quality measurement device in cooperation with the Biological and Agricultural Engineering Department at Kansas State University. This system automatically collects reflectance spectra from single-kernels and sorts kernels into damaged or undamaged categories. Preliminary results showed that color class, vitreousness, and internal insects can be detected with greater than 90% accuracy. Perten Instruments, Springfield, IL, has agreed to commercialize the new system. This system will be capable of measuring quality factors such as bunted kernels, protein, moisture, scab damage, and color class at grain elevators, thus allowing segregation at the first point of sale.

3. Development of Wheat Protein and Insect Detection Calibrations for the Single Kernel Characterization System (Model 4100). At industry request, we developed wheat protein and insect detection calibrations for a single kernel quality measurement instrument (SKCS 4170 - Perten Instruments). The calibrations included multiple classes of wheat and are being used by industry laboratories that have purchased this instrument. This information is used to purchase wheat for mills to optimize flour quality and to segregate insect infested wheat to minimize insect fragments in flour.

4. Development of Calibrations to Detect Wheat Vitreousness. At the request of the Grain Inspectors, Packers and Stockyards Agency (Federal Grain Inspection Service -FGIS), we are developing calibrations to detect the vitreousness of wheat using a GC 310 machine vision system manufactured by Foss. Vitreousness in wheat defines the appearance of the starch component of the endosperm. We have developed calibrations using samples that represent all vitreous defect classes. FGIS is currently collecting field samples to evaluate the system using 2001 crop year wheat. This system will reduce inspector error and labor in detecting vitreousness, allow quality and price to be more accurately accessed, and allow more precise segregation of wheat in order to improve end-use quality.

5. Development of an Objective Test for Bread Staling Using NIR. Bread staling can not be measured nondestructively or rapidly. Thus, we determined if NIR spectra from whole slices could be correlated to staling. We showed that staling could be more accurately determined from NIR spectra than from conventional destructive staling measurement devices. This technology could help bread makers more rapidly and accurately evaluate staling, and help vendors monitor staling of the in-store product. This rapid detection technology will also assist in the evaluation of anti-staling techniques.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Complete the development of a low-cost NIR system for detecting single kernel attributes and sorting based on these attributes.

2. Continue our investigation of other single kernel quality measurements such as protein and starch quality, and detection of transgenic attributes will be continued.

3. Continue image acquisition, calibration, and testing of the GC 310 to determine the performance and potential as an aid to grain inspectors and develop the "best" GC 310 calibration which will separate dark hard vitreous (DHV) kernels from non-DHV wheat kernels. We will also develop the "best" GC 310 calibration for the separation of hard vitreous and amber colored (HVAC) kernels from non-HVAC wheat kernels.

4. Continue to investigate the potential of single kernel NIRS to measure insect characteristics and the end-use quality of other commodities.

Specific tasks in 2003 will be to:

1. Develop a high-speed, low cost system for detecting single kernel attributes.

2. Integrate a machine vision system into the single kernel system.

3. Investigate technology to detect acts of bio-terrorism target at grain crops.

Specific tasks in 2004 will be to:

1. Investigate biosensors and other non-spectral sensors for rapidly measuring grain attributes.

2. Examine sampling, human, and analytical errors associated with measuring grain attributes.

3. Continue collaborative investigations of the potential of SKCS measurements to predict millability of wheat, investigate variables that influence system physical measurements, and expand the application of the system to physical measurements of other grains.

4. Continue with the development and implementation of NIR, machine vision, and mechanical sensors for measuring grain and grain product attributes.

Specific Cooperative Agreements for This Project Included:

a. The Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, Kansas

Cooperative Research and Development Agreements for This Project Included:

a. Perten Instruments, NA, Springfield, Illinois

Summary of 2001 Publications/Patents:

01. Dowell, F.E., Broce, A.B., Xie, F., Throne, J.E, Baker, J.E. Detection of parasitized fly puparia by using near-infrared spectroscopy. Journal of Near Infrared Spectroscopy. 2000. v. 8. p. 259-265.

02. Dempster, Richard E. A system for high resolution, spectral and spatial characterization. Proceedings of the International American Association of Cereal Chemists Meeting. 2000. p. 335.

03. Dowell, Floyd E., Psotka, James, Maghirang, Elizabeth, Walker, Duane E., Wang, Donghai, Xie, Feng. Measuring multiple attributes of single grain kernels using NIRS. Proceedings of the International American Association of Cereal Chemists Meeting. 2000. p.177.

04. Dowell, Floyd E., Throne, James E., Broce, A.B., Wirtz, R.A., Perez, Mendoza Joel, Baker, James E. Near-infrared spectroscopy applied to detecting parasitoids and hidden insect larvae, identifying coleoptera, and chronological age-grading. Proceedings of the 21st International Congress of Entomology. 2000. p. 1015.

05. Xie, F., Maghirang, Elizabeth, Pearson, T., Wicklow, D., Kramer, Karl J., Morgan, Thomas D., Dowell, Floyd E. NIRS applied to detecting single corn characteristics. 2000. Proceedings of the International American Association of Cereal Chemists Meeting. 2000. p.195.

06. Ram, M.S., Dowell, Floyd E., Seitz, Larry M., Lookhart, George L., Martin, J., Funk, D. Development of standard procedures for a simple, rapid test to determine wheat color class. 2000. Proceedings of the International AACC Meeting. 2000. p. 198.

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GRAIN QUALITY AND STRUCTURE RESEARCH UNIT

The mission of the Grain Quality and Structure Research Unit, which includes the Hard Winter Wheat Quality Laboratory, is to ensure a high quality and safe U.S. grain supply for our customers by: (1) conducting basic and applied research to identify the physical characteristics and structural/biochemical components that govern quality; (2) developing rapid, precise, and accurate predictive technologies for quality assessment; and (3) evaluating the end-use quality of breeding lines. Specific projects for this Unit include:

CRIS - 5430-44000-010-00D	Characterization of Grain Biochemical Components Responsible for End-Use Quality
CRIS - 5430-44000-012-00D	New Uses of Grain Sorghum
CRIS - 5430-44000-013-00D	Determination and Characterization of Wheat Quality (Hard Winter Wheat Quality Laboratory)

CRIS 5430-44000-010-00D

Characterization of Grain Biochemical Components Responsible for End-Use Quality

Project Leader: G. Lookhart

Investigators: O. Chung, G. Lookhart, D. Bechtel, L. Seitz, and M. Tilley

Full-Time Scientist Equivalents (SYs): 3.1 **Net Funding to Location per Year:** $ 634,955

Start Date: 07/05/99 **Term Date:** 07/04/04

Problem: Wheat is a major commodity in the world. Bread is one of the major products from wheat. Millions of loaves per day are produced in automated bakeries. The more automated a process becomes, the less opportunity for people operating the bakery to make changes needed due to variations in wheat flour properties. Since doughs are made in 6,000 to 10,000 pound batches, if the dough does not possess consistent and appropriate properties like mixing time requirement or non-stickiness, the bakery has to throw out that batch and clean the entire system. This is very costly in terms of ingredients and time. Rapid methods to predict wheat flour quality, without expensive and time-consuming tests, such as test baking, are urgently needed for the baking industry. Furthermore, rapid prediction methods for breadmaking quality would enhance the U.S. export of hard winter wheats, because international buyers of U.S. wheat want to know what quality they are receiving prior to purchase.

Objectives: The three components in wheat flour known to have an effect on the baking quality are starch, proteins, and lipids. Scientists in this unit study each of these components. The first step in understanding the roles these components play in end-use quality, is to be able to accurately and quickly measure the amounts, sizes and types of each fraction. Our goals are to develop rapid methods of analyzing the components of each fraction and to determine the types of lipids and the starch and protein size distributions in wheat in order to establish which populations are important in end-use quality for a variety of products. Additionally, we are identifying volatile compounds from breads that are associated with bread quality. Some volatiles are associated with flavors, while others might be used to monitor the progress of various steps during production of bakery products.

Results and Impact:

1. Further Evidence for the Existence of Three Types of Starch Granules in Wheat. Although starch comprises up to 62% of the weight of the mature wheat kernel, little is known about how starch forms within the seed. We used transmission electron microscopy to follow starch formation in structures in the kernel called amyloplasts from the day of flowering through grain maturation. The synthesis of the large, Type A starch granules was observed during the first week after flowering. Synthesis of medium, Type B granules was observed to begin from 10 to 12 days after flowering and the synthesis of a fraction of tiny granules (diameter .25 micrometers

or less), proposed as Type C, began from 17 to 21 days after flowering. The small size of Type C particles would produce a large area to volume ratio which may impact important properties such as water absorption, baking performance, etc.

2. Digital Image Analysis of Isolated Starch from Wheats of Different Classes and Application of Correction Factors to Determine Starch Size Distributions. Starch was isolated from different classes of wheat and analyzed using digital image analysis coupled to a light microscope to determine starch size distributions. The image analysis data was converted into volume data. Starch granules with diameters greater than 5 m were treated as oblate spheroids for calculating volumes. The measured equivalent diameter and an estimated starch granule thickness value were used for the major and minor axes in the oblate spheroid formula, respectively. Granules less than 5 m in diameter were treated as spheres. Starch granules that had their perimeter touching the edge of field of view had their volumes corrected using correction formulae. Correction formulae were developed for each wheat class or starch size distribution class. Correction formulae were important because without them, up to 50% of the large Type A granules could be under counted. Data indicated that there can be a wide variation in the size distribution of starch depending on wheat class and environmental effects. Some wheats exhibited a trimodal (three starch types) distribution of starch while others only exhibited a bimodal (two starch types) distribution. This data will be used to help predict wheat quality.

3. Incorporating a Barley HVA1 Gene into Wheat for Drought Tolerance. To improve drought tolerance, a gene containing the code for the protein, HVA1, from barley was introduced into a hard red winter wheat, Jagger, and a hard white winter wheat, Lakin. One transgenic Jagger wheat plant that tested positive for the HVA1 protein was obtained. Future studies will determine the impact of this genetic transformation on end-use quality, yield, and other important performance criteria.

4. Supercritical Fluid Extraction of Total Fat from Breakfast Cereals for Nutritional Labeling. In recent years, interest in developing analytical methods for the extraction of lipids from various cereal grains using a Supercritical Fluid Extraction (SFE) system has increased because of environmental, toxic exposure, and cost effects. The SFE methods are cost effective, less time consuming, and friendlier to the environment. We used this process to extract the total lipids from Ready-To-Eat Breakfast Cereals. We found that the best mixture for extraction of these lipids was a mixture of 1-propanol-water (3:1) 40% by volume with carbon dioxide to form a binary supercritical fluid at 10,000 psi, 120°C, and 3 mL/min flow rate. The AACC standard method (58-19) for acid hydrolysis was used as a reference method. We extracted 5 to 10 percent more total lipids by SFE than by acid hydrolysis depending on the sample matrix.

5. The Relationships of Free Lipids with Quality Factors in Hard Winter Wheat Flours. Hard winter wheat (*Triticum aestivum* L.) flours ($n=72$) were analyzed for free lipids (FL) and their relationships with quality parameters. Kernel hardness parameters, flour yields, and water absorptions had significant negative correlations with the level of monogalactosyldiglycerides (MGDG) present but positive correlations with the levels of digalactosyldiglycerides (DGDG). MGDG showed negative correlations with gluten content, but positive correlations with the

gluten index. The percentages of DGDG in FL had significant positive correlations among cultivars ($n=12$) with mixograph and bake mix times ($r=0.71$, $P<0.01$ and $r=0.67$, $P<0.05$, respectively), mixing tolerance ($r=0.67$, $P<0.05$), and bread crumb grain score ($r=0.71$, $P<0.01$). These results suggest that increasing DGDG in the free lipid fractions could improve wheat milling, dough mixing, and breadmaking quality attributes.

6. Free Lipids in Air-Classified High-Protein Fractions of Hard Winter Wheat Flours and their Effects on Breadmaking Quality. Free lipids (FL) were extracted from straight grade flours (SF) and their air-classified high-protein fractions (ACHPF) from nine different hard winter wheats. FL compositions of SF and ACHPF showed some significant differences in the levels of glycolipids and phospholipids. Fortification of SF with ACHPF by blending to reach a protein level of 13%, increased protein and gluten quantity and, as a result, loaf volume; but decreased the gluten index and crumb grain scores. Results also showed that a high neutral lipid content in ACHPF could decrease the gluten quality of fortified flours. As a result, one should be cautious when fortifying straight grade flours with ACHPF materials.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Characterize the molecular weight distribution of soluble and insoluble polymers of cereal grains and relate them to quality parameters. Protein fractions of commercially milled flours will be characterized and correlated with commercial quality parameters. Wheat cultivars will be characterized for size classes of starch granules and size and quantity of protein fractions and lipid components.

2. Transform wheats with the genes for HMW-GS 43 and 44 from *T. tauschii* and evaluate the resulting plants for expression of these proteins.

3. Characterize the biochemical components of wheat breeder and commercial samples and develop a statistical model to predict bread quality. Data from complete analysis of starch, protein, and lipid components will be correlated in various combinations with end-use (breadmaking, pizza, and tortilla) qualities. The final corrections for perimeter-touching-edge will be completed and will allow for the routine use of the system to measuring starch quality. Research to determine the specific sizes of starch that influence end-use product quality, such as bread crumb grain, will be initiated. Lipid components in wheats and/or flours will be characterized and the information obtained will be incorporated into an end-use quality prediction model.

4. Complete the evaluation of sensory and chemical data collected from a group of 750 samples and identify how volatile compounds can indicate problems in stored grain caused by insects, molds, and spontaneous heating.

5. Continue to provide odor vs. compound information to GIPSA/FGIS and suggest how the information could be used to aid odor assessments during grain inspections. Considerable data on volatiles in flour, doughs, bread ingredients, freshly baked breads, and freshly popped popcorn has been obtained. Complete the compilation of extensive chromatography data and identification of many compounds.

Specific tasks in 2003 will be to:

1. Study the interactions of the various biochemical components (proteins, lipids, and starch) and the molecular weight distributions of soluble and insoluble protein polymers and the effects of all these parameters on end-use (breadmaking, pizza, or tortilla) qualities. All information will be used to build a statistical model to predict end-use quality. In that way, a bigger picture (total interaction) of the wheat quality puzzle will be available.

2. Continue the investigations of gluten protein characteristics (molecular weight distributions of gliadin, soluble polymeric, and insoluble polymeric proteins).

3. Transform the genes responsible for GS 43 and 44 into red and white hard winter wheats. Analyze the transformed plants for specific GS and other proteins. Check rheological properties of those transformed plants.

4. Conduct additional analyses of the compositional differences that may relate to color or nutritional factors in red and white wheats.

5. Initiate microscopy studies to obtain better information on the location of specific compounds in the wheat kernel.

6. Continue with investigations of environment impacts on starch quality and lipid composition.

Specific tasks in 2004 will be to:

1. Continue the studies on the interactions of the various biochemical components in wheat flour and the molecular weight distributions of soluble and insoluble protein polymers. The effects of these interactions on the end-use quality of various products (pan bread, pizza, and tortilla) will be examined.

2. Continue to check for expression of transgenes and other proteins. We will characterize the molecular weight distributions of gliadin, soluble polymeric, and insoluble polymeric proteins from transgenic plants grown in the greenhouse and the field.

3. Check the rheological properties of transformed plants.

4. Continue microscopic studies to obtain better information on the location of nutritional compounds in the wheat kernel.

5. Continue studies of the environmental impact on starch quality and lipid composition.

Summary of 2001 Publications/Patents:

01. Bean, S.R., Hicks, C., Tuinstra, M., Lookhart, G.L. The use of SDS for extraction and analysis of sorghum proteins by free zone capillary electrophoresis. Cereal Chemistry. 2001. v. 78. p. 84-87.

02. Bean, S.R., Lookhart, G.L. Recent developments in high-performance capillary electrophoresis of cereal proteins. Electrophoresis. 2001. v. 22. p. 1503-1509.

03. Bean, S.R., Lookhart, G.L. Ultrafast capillary electrophoretic analysis of cereal storage proteins and its applications to protein characterization and cultivar differentiation. Journal of Agriculture and Food Chemistry. 2000. v. 48. p. 344-353.

04. Bietz, J.A., Lookhart, G.L., Bean, S.R.,, Sutton, K.H. Capillary electrophoresis: A state of the art technique of wheat protein characterization. Wheat Structure, Biochemistry, and Functionality. Royal Society of Chemistry (London). 2000. v. 212. p. 128-133.

05. Ohm, J.B., Chung, O.K. NIR transmittance estimation of free lipid content and its glycolipid and digalactosyldiglyceride contents using wheat flour lipid extracts. Cereal Chemistry. 2000. v. 77. p. 556-559.

06. Seitz, L.M., Ram, M.S. Volatile methoxybenzene compounds in grains with off-odors. Journal of Agriculture and Food Chemistry. 2000. v. 48. p. 4279-4289.

07. Shewry, P.R., Bechtel, D.B. Morphology and chemistry of the rye grain. Bushuk, W. editor. American Association of Cereal Chemistry. Inc., St.Paul, MN. Rye: Production, Chemistry, and Technology. 2nd edition. Chapter 5. 2001. p. 69-127.

08. Tilley, M., Bean, S.R., Seib, P.A., Sears, R.G. Lookhart, G.L. PCR amplification and DNA sequencing of high molecular weight glutenin subunits 43 and 44 from Triticum tauschii accession TA2450. Shewry, P.R., Tatham, A.S., editors. Royal Society of Chemistry Cambridge, UK. Wheat Gluten. 2000. pp. 105-109.

09. Vasil, I.K, Bean, S., Zhao, J., McCluskey, P., Lookhart, G., Zhao, H., Altpeter, F., Vasil, V. Evaluation of baking properties and gluten protein composition of field grown transgenic wheat lines expressing high molecular weight glutenin gene 1Ax1. Journal of Plant Physiology. 2001. v. 158(4). p. 521-528.

10. Woods, K.M., Tilley, M., Iseli, A., Upton, S.J., Montelone, B.A., Khramstov, N.V. Sequence of the gene encoding hsp90e from Cryptosporidium parvum. GenBank accession #AF038559. DNA Sequence The Journal of DNA Sequencing and Mapping. 2000. v. 10. p. 339-342.

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CRIS 5430-44000-012-00D

NEW USES OF GRAIN SORGHUM

Project Leader: S. Bean

Investigators: S. Bean, O. Chung

Full-Time Scientist Equivalents (SYs): 1.1

Net funding to Location per Year: $ 404,505

Start Date: 10/01/01

Term Date: 08/31/02

Problem: While sorghum is a relatively new crop in the United States, it is a staple food crop in many countries. Worldwide sorghum production in 1998 was 61.7 million metric tons (mmt). The U.S. produced 13.2 mmt in 1998 on 3.1 million hectares, representing ~20% of world production. Approximately 30 to 50% of the U.S. sorghum crop is exported. In recent years, however, sorghum production has declined in the U.S. Sorghum is primarily used for feed in the U.S. whereas ~30 to 40% of worldwide production is used as human food. Sorghum does not possess the same functionality as wheat and therefore it is difficult to produce typical baked products from sorghum. For people who cannot consume wheat and closely related cereals, such as rye and barley, sorghum represents a "safe" food. Sorghum may also have unique phytonutrients that can help to improve human and animal health. Therefore, it is highly desirable to be able to produce baked goods and other food products acceptable to U.S. and foreign consumers. The ability to produce higher quality products will also benefit some countries where sorghum is a food staple, often countries where malnutrition and starvation are problems. In addition to these benefits, producing higher quality sorghum food products will lead to increased sorghum utilization and therefore provide more domestic and foreign export markets.

Objectives: Specific objectives of this research are to: develop a better understanding of the role of sorghum proteins in digestibility in order to increase the nutritional quality of sorghum; develop a better understanding of the role of proteins, starch, and lipids in the functionality of sorghum in sorghum foods; identify key components that are important to functionality; develop rapid and reliable methods for measuring key components to assist in predicting quality; and investigate the potential for modifying sorghum to improve the functionality and nutritional quality of sorghum.

Results and Impact:

1. New Scientist Hired. Dr. Scott Bean joined the Grain Quality and Structure Research Unit in October as a Research Chemist. Dr. Bean received his M.S. and Ph.D. degrees in Grain Science from the Department of Grain Science and Industry, Kansas State University. Dr. Bean's expertise is in cereal biochemistry and analytical methods for characterizing cereal proteins using instruments including capillary electrophoresis and liquid chromatography. In addition, Dr. Bean has experience in studying structure-function relationships of cereal biomolecules that relate to end-product quality. As Lead Scientist of the Sorghum Project, his responsibilities will include the biochemical characterization of grain sorghum for both human and feed uses, cultivar

identification, their relationships to functional and nutritional quality, and providing information on quality biochemical determinants for sorghum breeders to improve lines suitable for traditional and novel uses. This is a new project created in response to efforts by the National Grain Sorghum Producers to enhance sorghum value in food and non-food uses.

2. Genetic Analysis of Kafirins and their Phenotypic Correlations with Feed-Quality Traits, *in vitro* Digestibility, and Seed Weight in Grain Sorghum. Twenty-three entries of grain sorghum [*Sorghum bicolor* (L.) Moench], including eight inbred lines (five males and three females) and 15 hybrids, were evaluated to determine the proportion of II, and -I-kafirins (sorghum proteins). Kafirin contents then were compared with the amounts of crude protein (CP), fat (FAT), and starch (STA); protein digestibility (PD); *in vitro* dry matter disappearance (IVDMD); and seed weight (SW). The male lines included three normal-seeded lines ('TX2737', 'TX435', and 'P954063') and two large-seeded lines ('Eastin1' and PL-1). Female lines consisted of three common U.S. seed parent lines ('Wheatland', 'Redlan', and 'SA3042'). The lines and their hybrids were grown under dryland conditions at two locations in Kansas using a randomized complete block design. The effects of genotype, location, and males were significant for all kafirins. Wide variations in composition and general combining ability for kafirin content were noted among parent lines and hybrids.

Goals for 2002, 2003, and 2004:

Specific Tasks for 2002 will be to:

1. Study the effects of traditional and enzymatic nixtamalization (an alkaline steeping process used to produce sorghum masa) on sorghum proteins. Sorghum nixtamal proteins will be characterized using traditional and enzymatic methods. Changes observed between the two nixtamalization procedures will be documented and related to their functionality in food products.

2. Investigate the relationships between sorghum protein biochemistry and composition and biodegradable film formation. The biochemical properties of sorghum proteins from several sorghum cultivars will be characterized by measuring molecular weight, surface hydrophobicity, charge density, and amino acid composition. These properties will be related to protein film quality.

3. Improve existing methods for extraction and analysis of sorghum proteins.

Specific Tasks for 2003 will be to:

1. Develop methods for analyzing phenolic compounds in sorghum by capillary electrophoresis.

2. Investigate the environmental impact and other factors that influence the concentrations of phenolic acids in sorghum.

3. Optimize the conditions necessary to produce high quality biodegradable films.

Specific Tasks for 2004 will be to:

1. Investigate the formation of dough using sorghum flour and composites of sorghum and wheat flour.

2. Continue to optimize the formation of biodegradable films from sorghum proteins. Extraction methods for sorghum proteins suited to industrial use in film production will be developed.

3. Investigate single kernel hardness in sorghum and its relationship to protein composition and biochemistry as well as milling properties.

Summary of 2001 Publications/Patents:

01. Bean, S.R., Hicks, C., Tuinstra, M., Lookhart, G.L. 2001. Use of SDS for extraction and analysis of sorghum proteins by free zone capillary electrophoresis. Cereal Chem. 78:84-87.

02. Hicks, C., Bean, S.R., Lookhart, G.L., Pedersen, J.F., Kofoid, K.D., Tuinstra, M.R. 2001. Genetic Analysis of Kafirins and their Phenotypic Correlations with Feed-Quality traits, *In Vitro* Digestibility, and Seed Weight in Grain Sorghum. Cereal Chem. 78:412-416.

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CRIS 5430-44000-013-00D

Determination and Characterization of Wheat Quality
(Hard Winter Wheat Quality Laboratory)

Project Leader: O. Chung **Investigators:** O. Chung, G. Lookhart, M. Tilley, and B. Seabourn

Full-Time Scientist Equivalents (SYs): 2.9 **Net Funding to Location per Year:** $ 1,109,664

Start Date: 08/01/00 **Term Date:** 08/31/04

Problem: Achieving acceptable end-use quality for milling and baking is an important objective of wheat breeding programs throughout the U.S. hard winter wheat region. On average, it requires 10-14 years for a new wheat variety to be developed and enter the commercial market place. The demand for consistent quality by the domestic milling and baking industry, and an increasingly competitive export market, emphasize the need for end-use quality as a major breeding objective. The use of unadapted germplasm to enhance genetic diversity or incorporating desirable pest resistance traits into commercial varieties also requires implementation of efficient end-use quality evaluation systems. A method for screening undesirable experimental lines from breeding programs is highly desirable, and would facilitate more rapid development of those lines that would most benefit commercial markets. There is a very real need in the commercial milling and baking industry for a more accurate and rapid method for evaluation of the end-use properties of wheat and flour. For example, considerable time and expense could be saved by commercial bakeries if an online quality monitoring system could be incorporated into the dough formulation and mixing process.

Objectives: One of the main goals of this project is to extend our knowledge of the interaction of the basic components (protein, starch, lipid, and water) in a flour-water system, and to thus provide a more rapid and objective means for determining the end-use performance of a given flour sample. This new information will ultimately facilitate the increased utilization of U.S. wheat flour for new and unique commercial products, as well as in export markets. An equally important goal for this project is to develop the tools needed to segregate wheats based on quality attributes at the first point of sale. In addition, quality analysis tools that can be applied to very small samples are also needed to provide breeders with the performance evaluation of new cultivars.

Results and Impact:

1. Wheat Quality Relational Database. The wheat quality database was updated with the results from the 2001 crop year quality analyses. The web page (http://gqul.usgmrl.ksu.edu/gqu/HWWQL/HWWQLHome.htm) for the Hard Winter Wheat Quality Laboratory (HWWQL) was developed so that breeders and other industry customers could

easily access regional performance nursery data via the internet. This is a continuous process in which the database is expanded each year.

2. Evaluation of Chemical Changes During Dough Formation in Real Time. Total reflectance spectra were collected in the mid-Infrared range on a variety of HRW flour samples that contained the same level of protein, but that had very different rheological properties. Results showed a simultaneous decrease in α-helical secondary structure and an increase in β-sheet secondary structure over time throughout the mixing cycle as the dough developed. The α-helical structure in proteins is thought to be tightly coiled like a spring while the β-sheet is more open and the proteins are more extended. Thus, our data show that, during dough formation, the protein structure is changing from the α-helical form to the β-sheet. The ratio of these two structural components provides a curve from which the optimum development time for the dough can be determined. Thus, this analytical technique, that is based entirely on the chemistry of the dough system, can provide the optimum mix time without subjective interpretation. This technology could potentially be utilized in the on-line monitoring of dough performance during large-scale processing, which would lower overall production costs by reducing labor costs and training, processing downtime, as well as optimizing ingredient input.

3. Correlation of Single Kernel Analyses with End-Use Quality. Many researchers who are working to evaluate wheat end-use quality (milling and breadmaking) in breeding programs and industry do not have an experimental milling or baking facility. The number and/or amount of wheat samples available are not always enough to perform milling and baking tests. At the HWWQL, we have studied the relationship between end-use quality and commercially available cereal testing instrumental data, using 1300 different wheat samples. Our study showed significant correlations between single kernel characterization system (SKCS) parameters and many common quality parameters such as test weight, 1000 kernel weight, percentage of large kernels, and milling yield. The prediction models that were developed from SKCS parameters, combined with wheat and flour protein contents, accurately predict milling yield and bread loaf volume. Furthermore, additional computer-analyzed mixograph parameters improved the prediction model of bread loaf volume. Thus, simple and rapid cereal testing instruments have proven valuable for indirect prediction of milling and breadmaking quality when rapid evaluation of many samples (where sample size is limited) is required in breeding programs and industry.

4. Prediction of Quality Characteristics of Hard Winter Wheats using Single Kernel and Mixograph Parameters. Single kernel and mixograph parameters of hard winter wheats were gathered from federal regional nurseries from 1990 to 1999. Eight characteristics and 12 machine parameters obtained from the Single Kernel Characterization System were used to develop a prediction model of flour yield by continuum regression. Flour yield showed mean values of 68.8% and standard deviations of 6.6 and 3.5 for calibration (n=1200) and validation sets (n=300), respectively. Prediction model of flour yield showed an R2 of 0.696 for calibration set and 0.684 for validation set. Wheat protein content, single kernel characteristics, and objective computer-analyzed mixograph parameters were also used to develop prediction models of breadmaking properties.

5. Effects of Flour Particle Size on Loaf Volume and Internal Characteristics of Experimental Pup-Loaf Bread. Flours with three different protein contents (PC) (9.8%, 11.9%, and 13.2% on a 14% mb) were used to study the effects of flour particle size (PS) on the experimental breadmaking properties including loaf volume (LV) and internal characteristics such as crumb grain, fineness, and elongation ratio. Flour PS distribution affected both LV and internal characteristics of experimentally baked pup-loaf breads. Medium sized particles (53 - 75 micrometer) produced the highest LV and small particles (<53 micrometers) produced the lowest LV. Crumb grain scores were higher for the smallest particle size flour except for the lowest protein flour.

6. Monitoring the Fate of DNA During Milling and Baking Processes. The use of ingredients derived from genetically derived materials is increasing. Processing of flour has a significant effect upon our ability to determine the presence or absence of genetically modified DNA. We analyzed the effects of the milling and baking processes on wheat DNA as an indicator of the changes that occur during processing. As wheat is processed into flour and baked, the DNA is broken into smaller and smaller pieces. However, the DNA-based analytical method used is sensitive enough to detect low levels of genetic materials in finished bakery products and should be able to detect the presence of transgenic genes. The labeling of genetically modified foods is dependent on the development of methods that are capable of sensitive and accurate detection. Defining the sensitivity of DNA based detection will assist in designing appropriate parameters for testing baked products.

7. Quality Characteristics of Hard Winter and Spring Wheats Grown Under an Over-Wintering Condition. Twelve (12) cultivars of each hard winter wheat (HWW) and hard spring wheat (HSW) were grown three crop years in a unique growing environment in California that allows for synchronous grain fill of all genotypes thus removing a normally strong environmental component and allowing a better investigation of the genetic component differences. Through the three years, the HSW showed significantly higher mean values of protein and gluten contents, kernel hardness, and loaf volume but lower gluten index than HWW. Specifically, wheat near-infrared reflectance hardness score (NIR-HS) overlapped very little among individual cultivars of the two classes. Therefore, differences in wheat hardness between HWW and HSW might be caused by genetic background. The HWW and HSW, grown side by side, could be clearly classified, using wheat characteristics including single kernel parameters in addition to NIR-HS. Principal component regression analysis indicated that flour yields and loaf volumes could be estimated using wheat characteristics and/or single kernel parameters, showing a good potential for screening early generation breeding lines.

8. Positive Effects of Growing Environment on Wheat Protein Content and Breadmaking Quality. Plants of the hard red spring wheat 'Butte 86' and the hard red winter wheats 'Cheyenne' and 'Arapahoe' were grown in pots under controlled environmental conditions. All three cultivars have the same complement of high molecular weight glutenin subunits, including Dx5 and Dy10, which contribute to good gluten quality. To understand the effects of environment on breadmaking quality, wheat was grown under different regimens of fertilizer, water, and daytime

and nighttime temperatures. Post-anthesis fertilizer increased wheat protein content per wheat grain while heat and drought reduced the duration of starch deposition, and thus reduced kernel weight. In the absence of post-anthesis fertilizer, heat and drought increased flour protein content. Loaf volume and SDS sedimentation volume were highly correlated with flour protein content, regardless of the environmental treatment. Some mixograph parameters also were correlated with protein content, regardless of environmental treatment. The results indicate that flour protein quality for these wheat cultivars were remarkably stable over a wide range of protein contents, whether achieved by varying fertilizer, temperature, or water during grain fill.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Continue the mandated activity of the HWWQL; evaluation of the end-use quality of wheat breeding lines. Standard tests will be conducted to evaluate wheat quality and end-use performance such as physical grain tests and milling, mixing, and baking tests, in addition to the characterization of biochemical quality determinants.

2. Add graphic images of the mixograph curve for each wheat line in the Hard Winter Wheat Quality Database for the next distribution of the database, as well as an interface for user-selected statistical analyses. We will remove obsolete or undesirable/unnecessary quality parameters and add new quality parameters in order to better predict end-use quality.

3. Continue to improve the NIR predictive equations for quality factors by using more up-to-date prediction methods and expanding our database until the predictability is high enough to meet industry needs. The effect of variation of kernel hardness and weight in a wheat sample on milling and baking properties will be investigated.

4. Continue to study the relationships between wheat physical characteristics and end-use properties, which may be helpful to segregate wheats based on quality. Work on measuring protein structural changes during dough formation and subsequent development of correlations with end-use performance will continue.

5. Develop methods utilizing available technology for the detection of genetically modified (GM) crops and ingredients derived from them in processed baked goods.

Specific tasks in 2003 will be to:

1. Continue the mandated activity of the HWWQL evaluation of end-use quality of wheat breeding lines. Standard tests will be conducted to evaluate wheat quality and end-use performance such as physical grain tests, milling, mixing, and baking tests, in addition to characterization of biochemical quality determinants.

2. Continue to study the changes that occur in proteins, starches, and lipids during dough formation. FTIR and Raman analyses will be used to evaluate the influence of specific bonds, such as disulfide or dityrosine bonds, within individual protein molecules and between proteins or other chemical constituents on end-use performance.

3. Continue to develop methods for the detection of genetically modified (GM) crops and ingredients derived from them in processed baked goods.

Specific tasks in 2004 will be to:

1. Continue to add graphic images of the mixograph curve for each wheat line in the HWWQL database for the next release of the database, as well as an interface for user-selected statistical analyses.

2. Evaluate both genetic and environmental effects on end-use quality and biochemical components (composition) with breeders samples grown at various locations

3. Continue with the instrumental analyses of the interaction of the various chemical components in flour during dough formation; and analyze DNA levels from wheat-based products during processing stages.

Specific Cooperative Agreements for This Project Included:

a. The Department of Grain Science and Industry, Kansas State University, Manhattan, Kansas

Summary of 2001 Publications/Patents:

01. Chung, O.K., Ohm, J.B., Caley, M.S., Seabourn, B.W. Prediction of baking characteristics of hard winter wheat flours using computer-analyzed mixograph parameters. Cereal Chemistry. 2001. v. 78. p. 493-497.

02. Chung, O.K., Ohm, J.B. Cereal lipids. Kulp, K., Ponte, J.G., Jr., editors. Marcel Dekker, Inc., New York, NY. Handbook of Cereal Science and Technology; 2nd edition; Chapter 14. 2000. p. 417-477.

03. Chung, O.K., Pomeranz, Y. Cereal processing. Nakai, S., Modler, H.W. editors. John Wiley & Sons, Inc., New York, NY. Food Proteins: Properties and Applications; Chapter 6. 2000. v. II. p. 243-307.

04. Chung, O.K., Dowell, F.E., Lookhart, G.L., Ohm, J.B., Bean, S.R., Steele, J.L., Seitz, L.M., Bechtel, D.B., Ram, M.S., ..., Martin, C.R., Zayas, I.Y., Hubbard, J.D., Tilley, M., Seabourn, B.W., Caley, M.S., ..., Wilson, J.D., Baker, J.E., Throne, J.E., Flinn, P.W., Sauer, D.B., Chang,

C.S., Koeltzow, D.E. Wheat research in the U.S. Grain Marketing Research Laboratory. Annual Wheat Newsletter. 2000. v. 46. p. 205-219.

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PLANT SCIENCE AND ENTOMOLOGY RESEARCH UNIT

The mission of the Plant Science and Entomology Research Unit is to develop multiple disease and insect pest resistant wheat and alfalfa germplasms. In addition, this Unit is actively involved in the development of DNA markers for both pest resistance and quality traits. These markers are short pieces of genetic material that can be used to determine if new varieties carry specific pest resistance or quality traits. Specific research projects for this Unit include:

CRIS - 5430-21220-004-00D	Genetic Enhancement of Wheat and Alfalfa for Resistance to Multiple Biotic Stress

CRIS 5430-21220-004-00D

Genetic Enhancement of Wheat and Alfalfa for Resistance to Multiple Biotic Stress

Project Leader: R. Bowden

Investigators: R. Bowden, G. Brown-Guedira, J. Fellers, M. Chen, and vacant

Full-Time Scientist Equivalents (SYs): 5.0 **Net Funding to Location per Year:** $ 1,511,881

Start Date: 10/01/98 **Term Date:** 09/30/03

Problem: Crop yields and quality of wheat and alfalfa in the southern Great Plains are reduced by an estimated 20 to 30% each year due to disease and insect damage. Host plant resistance is the most economical and environmentally sound method of pest control. This project is directed toward the discovery and utilization of new genetic systems to control major diseases and insect pests of wheat and alfalfa. Modern techniques of genomics analysis are being used in the crop plants, disease organisms, and insect pests to understand the interaction of the plants and pests at the most fundamental level. Genes controlling resistance to several diseases and insect pests are being identified and analyzed. The functions of these genes will be identified and studied to develop an understanding of how wheat and alfalfa interact with pests and pathogens to reduce crop losses. The knowledge gained is being applied to the development of new germplasms and cultivars of wheat and alfalfa.

Objectives: The main objective of this project is to increase the diversity and performance of wheat and alfalfa germplasm used in public and private breeding programs. Molecular and statistical techniques will be developed to facilitate the application of marker-assisted breeding technology to the improvement of the crops. Individual genes from wheat and alfalfa plants, and from pathogens and insect pests will be identified and studied to develop an understanding of the genes involved in the interactions of the plants and their pests. Information gained will lead to the development of plant lines with diverse arrays of genes.

Results and Impact:

1. Analysis of Plant Genes Involved in Response to Disease and Insect Attacks. Plant genes involved in the development of a response to disease or insect attack are poorly understood. Over 5,600 fragments involved in the response of wheat to Hessian fly, Fusarium head scab, Karnal bunt, and leaf rust were identified and their molecular sequence determined. The structures of these gene fragments are being investigated to develop an understanding of the fundamental processes involved in plant defenses. We have been able to determine a subset of genes that are affected by infection by these pathogens. This work is the foundation of future research that will develop new approaches to develop resistance to the plant diseases listed above and protect crop yields.

2. Development of Germplasm that Inhibits Black Stem in Alfalfa. Every year, Summer Black Stem of alfalfa causes as much as 20% yield loss. High levels of resistance have not been found; however, a germplasm was developed that inhibits the development of the disease for a period of time significantly longer than the parent sources. This germplasm will contribute to a reduction in disease severity in the cultivated crop. The alfalfa seed chalcid is an insect that feeds on seeds as they develop in the pod, virtually eliminating alfalfa seed production in the Southern Great Plains. A germplasm with dense gland-tipped hairs on the seed pods was developed, and showed 20% reduction in the incidence of seed chalcid feeding in the first year.

3. Use of Chloroplast Components to Distinguish Between Alfalfa Populations. A method of distinguishing alfalfa populations based on differences in parts of the chloroplast genome was developed and tested on more than 100 populations. This method has the potential to be applied in the "fingerprinting" of alfalfa cultivars, contributing to the plant improvement effort by allowing the distinction of individual cultivars, and providing a tool to aid in the selection of diverse parents, which is highly desirable in alfalfa breeding.

4. Development of Germplasm that Decreases Seed Chalcid Attack of Alfalfa. The alfalfa seed chalcid is an insect that feeds on seeds as they develop in the pod, virtually eliminating alfalfa seed production in the Southern Great Plains. A germplasm with dense gland-tipped hairs on the seed pods was developed, and showed 20% reduction in the incidence of seed chalcid feeding in the first year.

Goals for 2002, 2003, and 2004:

Specific tasks in 2002 will be to:

1. Quantify the level of effectiveness of the disease resistance markers thus far identified in wheat in cooperation with researchers in several locations.

2. Identify the physical location of wheat genes involved in resistance to Karnal bunt, Fusarium head scab, and leaf rust and investigate the expression of these genes under various environmental conditions.

3. Identify agronomically acceptable wheat germplasm containing new genes for resistance to leaf rust and powdery mildew derived from the wild relative, *Ae. speltoides*.

4. Identify and clone the genes in Hessian fly larvae involved in feeding and plant injury.

5. Continue the transfer of useful genes from related species to wheat and the identification of markers linked to disease and insect resistance genes.

6. Compare the population structure of *Gibberella zeae*, the cause of wheat head blight, in North America, South America, and South Korea. New mapping populations of *G. zeae* will be created and the aggressiveness genes will be located on a genetic map.

7. Continue to screen wheat breeding lines from several breeding programs for resistance to leaf rust.

Specific tasks in 2003 will be to:

1. Use molecular markers that are linked to disease and pest resistance genes from wheat for crop improvement to guide incorporation of the genes into adapted varieties and identify wheat lines having 2-3 effective genes for resistance to leaf rust using molecular marker technology. The resulting germplasm and molecular markers will speed the process of developing cultivars with more durable resistance to wheat leaf rust and will be released to the public.

2. Identify specific genes involved in the parasitic ability of Hessian fly to wheat and evaluate progenies from crosses of wheat and related species in field and greenhouse.

3. Transfer useful markers to wheat breeding programs for marker assisted selection.

4. Initiate genetic studies of *Tilletia indica*, the Karnal bunt fungus.

Specific tasks in 2004 will be to:

1. Develop a collection of molecular markers that can be used to identify the lineage of a wheat variety.

2. Develop molecular genetic wheat libraries that can be used as sources to clone genes for resistance to various pathogens.

3. Identify genes within the pathogens that cause disease.

4. Collaborate with wheat breeding programs to develop and deploy improved techniques for marker assisted selection.

5. Continue the evaluation of progenies from crosses of wheat and related species in the greenhouse and multiple field locations and the release of new pest resistant germplasm.

Specific Cooperative Agreements for This Project Included:

a. The Department of Entomology, Kansas State University, Manhattan, Kansas
b. The Department of Plant Pathology, Kansas State University, Manhattan, Kansas

Summary of 2001 Publications/Patents:

01. Skinner, D.Z. Nonrandom hypervariability in chloroplast DNA of Medicago sativa. Theoretical and Applied Genetics. 2000. v. 101 p. 1242-1249.

02. Yu, T.T., Skinner, D.Z., Liang, G.H., Trick, H.N., Huang, B., Muthukrishnan, S. Agrobacterium-mediated transformation of creeping bentgrass using GFP as a reporter gene. Hereditas. 2000. v. 133 p. 229-234.

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07. Baenziger, P.S., Moreno-Sevilla, B., Peterson, C.J., Shelton, D.R., Elmore, R.W., Nordquist, P.T., Klein, R.N., Baltensperger, D.D., Nelson, L.A., McVey, D.V., Watkins, J.E., Hein, G., Hatchett, J.H. Registration of 'Millennium' wheat. Crop Science. 2001. v. 41 p. 1367-1368.

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09. Sears, R.G., Martin, T.J., McCluskey, P.J., Paulsen, G.M., Heer, W.F., Long, J.H., Witt, M.D., Brown-Guedira, G.L. Registration of 'Heyne' wheat. Crop Science. 2001. v. 41. p. 1367.

10. Hill-Ambroz, K.L., Fellers, J.P., Brown-Guedira, G.L. Construction of a wheat cDNA subtraction library for Karnal bunt disease resistance analysis. Plant and Animal Genome IX Conference. 2001. Abstract p. 34.

11. Fellers, J., Hill-Ambroz, K., Li, W., Gill, B.S. Expression patterns of genes from a head scab infected spike cDNA library. National Fusarium Head Blight Forum. 2000. p. 26.

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WIND EROSION RESEARCH UNIT

The mission of the Wind Erosion Research Unit is to increase our understanding of wind erosion processes; develop reliable predictive tools; develop control practices; and disseminate information and technology for sustaining agriculture, protecting the environment, and conserving natural resources. The main research project for this Unit is:

CRIS - 5430-11120-002-00D Wind Erosion Processes, Assessment, and Control

CRIS 5430-11120-005-00D

Wind Erosion Processes, Assessment, and Control

Project Leader: E. Skidmore

Investigators: E. Skidmore, J. Tatarko, L. Wagner, and L. Hagen

Full-Time Scientist Equivalents (SYs): 4.0 **Net Funding to Location per Year:** $ 942,187

Start Date: 10/01/95 **Term Date:** 09/30/00

Problem: Wind erosion causes about 44 percent of the 2.13 billion tons per year of soil loss from U.S. cropland. In the Great Plains alone, about 5 million acres are moderately to severely damaged by wind erosion each year. Wind erosion physically removes the most fertile portion of the soil from the field. Some soil from damaged land enters suspension and becomes part of the atmospheric dust load. Dust obscures visibility, pollutes the air, causes automobile accidents, fouls machinery, and imperils animal and human health. Blowing soil also fills road and irrigation ditches; buries fences, reduces seedling survival and growth; lowers marketability of vegetable crops; increases susceptibility of plants to diseases; and contributes to transmission of some plant pathogens. Deposition of wind-blown sediments in drainage pathways and on water bodies significantly deteriorates water quality. Wind erosion continues as a threat to agricultural sustainability and environmental quality.

Objectives: The main goal of this project is to increase our understanding of wind erosion and dust emission processes and provide a scientific basis for development of prediction technology and control measures. Specific emphasis will be placed on the continued development of a Wind Erosion Prediction System (WEPS). This is an expert system that will provide a more reliable science-based technology for improving erosion prediction, developing soil-, climate-, and crop-specific control strategies, and for assessing erosion damage and environmental impact.

Results and Impact:

1. Field Testing of WEPS 1.0 and Additional Training. From November 2000 through April 2001, samplers were installed in a field near Burlington, CO to measure wind blown sediment flux and automated devices (Sensits) were deployed for continuous detection of saltation. A weather station recorded relevant meteorological data. Detailed measurements of the field surface were taken on three dates. Data were analyzed and used for WEPS simulations. Areas where WEPS needs improvement were pointed out. Training of selected state-level NRCS employees on the Wind Erosion Prediction System model (WEPS 1.0) for agency testing and evaluation purposes has been completed. Five additional regional meetings (Champaign, IL; Murfreesboro, TN; Rapid City, SD; Ft. Worth, TX; and Reno, NV) are currently underway to instruct those that will be training the NRCS field office employees on the correct use and implementation of WEPS 1.0

within their agency during the next year. Training materials have been developed to assist these instructors, including a WEPS 1.0 User's Guide manual and CD-Rom based video tutorials.

2. Modifications to WEPS 1.0. Many improvements have been made to WEPS 1.0 in response to NRCS reviewers' comments and suggestions. Enhancements to the WEPS management and crop rotation editor have been completed and a special file format created to allow sharing of management rotation files between WEPS 1.0 and RUSLE2 (the model that defines water erosion of the soil). Interface improvements such as these along with bug fixes in the science model will make WEPS 1.0 easier to use and more robust for the NRCS field office employee.

Goals for 2002, 2003, and 2004:

Specific tasks for 2002 will be to:

1. Continue assisting NRCS in implementing WEPS 1.0 by providing technical support and guidance as NRCS finishes developing training materials and databases for WEPS 1.0. We will also assist NRCS as they deploy WEPS 1.0 throughout their agency.

2. Review customer needs for direction.

Specific tasks for 2003 will be to:

1. Continue to address immediate, high priority customer needs regarding WEPS 1.0. With direction provided by our customers, we will plan for enhancements and improvements to WEPS that will meet their stated future needs.

Specific tasks for 2004 will be to:

1. Execute plans to address customers' future wind erosion and air quality prediction needs including extending WEPS 2.0 to forest, crop, and other disturbed lands and developing viable practices for reducing dust emissions from wind erosion.

Specific Cooperative Agreements for This Project Included:

a. The Natural Resources Conservation Service, Washington, D.C.
b. The Department of Agronomy, Kansas State University, Manhattan, Kansas

Cooperative Research and Development Agreements for This Project Included:

a. The Department of the Army, Washington, D.C.
b. The Environmental Protection Agency, Washington, D.C.

Summary of 2001 Publications/Patents:

01. Armbrust, D.V. Plant Tolerance to Sandblast Damage. Ascough II, J.C., Flanagan, D.C., editors. Soil Erosion Research for the 21st Century Proceedings. 2001. p. 67-70.

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SUMMARY OF GMPRC RESEARCH RESULTS for 2001

Item **Page No.**

I. Biological Research Unit - Control of Stored-Product Insect Pests

Management of Stored-Product Insect Pests in Food Processing Plants and Warehouses..... 2
Understanding Insect Pest Behavior in Food Processing Facilities..... 3
Maternal Larvicidal Gene Identified..... 6
History of Grain-Protecting Biopesticide Development Reported..... 7
New Forms of Insecticidal Protein Developed..... 7
Indianmeal Moth Blood Contains Proteins That Supply Essential Amino Acids During Metamorphosis and Reproduction..... 7
Zinc and Manganese in Insect Teeth Are Important Minerals for Development and Infestation of Grain..... 7
Gene Important for Insect Development Cloned..... 8
Ovarian Physiology Used to Age-grade Weevils..... 8
cDNA for Recognition Protein Cloned from Indianmeal Moth Expression Library..... 8
Determine the Impact of Biological Insect Control Methods on Beneficial Insects..... 12
Evaluation of the Effectiveness of Biological Pest control Methods on the Red Flour Beetle..... 12
Development of Digestion Inhibitors as an Insect Pest Control Method for Beetles..... 13
Recognition Methods Include Surface Chemicals..... 13
Development of Area-Wide Integrated Pest Management Strategies for Implementation..... 16
Development of a Population Growth Model for Stored-Grain Insect Pests in Concrete Silos..... 17
Detection of Insect Fragments Using NIRS..... 17

II. Engineering Research Unit - Grain Handling and Quality Measurement

Identity Preserved Grain Handling in Grain Elevators..... 22
Evaluation of a Pre-filling Bin Sanitation Method Using Heat..... 23
Evaluation of Temperature Management Strategies to Reduce Pesticide Usage..... 23
Dust Control in an Elevator Facility Using Water Mist..... 23
Development of Components for a U.S. Grain Bin Sealing Standard..... 24
Pre-filling Heat Treatment of On-Farm Grain Storage Bins..... 24
The Use of Optical Sensors to Detect Karnal Bunt in Wheat..... 26
Development of a Low-Cost, Single Kernel Quality Measurement Device..... 27
Development of Wheat Protein and Insect Detection Calibrations for the Single Kernel Characterization System (Model 4100)..... 27
Development of Calibrations to Detect Wheat Vitreousness..... 27
Development of an Objective Test for Bread Staling Using NIR..... 27

III. Grain Quality and Structure Research Unit - Wheat & Sorghum Quality Analysis

Further Evidence for the Existence of Three Types of Starch Granules in Wheat..... 32
Digital Image Analysis of Isolated Starch from Wheats of Different Classes and Application of Correction Factors to Determine Starch Size Distributions..... 33
Incorporating a Barley HVA1 Gene into Wheat for Drought Tolerance..... 33
Supercritical Fluid Extraction of Total Fat from Breakfast Cereals for Nutritional Labeling..... 33
The Relationships of Free Lipids with Quality Factors in Hard Winter Wheat Flours..... 33
Free Lipids in Air-Classified High-Protein Fractions of Hard Winter Wheat Flours and their Effects on Breadmaking Quality..... 34

Wheat Quality Relational Database (update)..... 38
Evaluation of Chemical Changes During Dough Formation in Real Time..... 39
Correlation of Single Kernel Analyses with End-Use Quality..... 39
Prediction of Quality Characteristics of Hard Winter Wheats using Single Kernel and Mixograph Parameters..... 39
Effects of Flour Particle Size on Loaf Volume and Internal Characteristics of Experimental Pup-Loaf Bread..... 40
Monitoring the Fate of DNA During Milling and Baking Processes..... 40
Quality Characteristics of Hard Winter and Spring Wheats Grown Under an Over-Wintering Condition..... 40
Positive Effects of Growing Environment on Wheat Protein Content and Breadmaking Quality..... 40
Genetic Analysis of Kafirins and their Phenotypic Correlations with Feed-Quality Traits, *in vitro* Digestibility, and Seed Weight in Grain Sorghum..... 45

IV. Plant Science and Entomology Research Unit - Wheat and Alfalfa Genome Mapping and Disease and Insect Pest Resistance

Analysis of Plant Genes Involved in Response to Disease and Insect Attacks..... 48
Development of Germplasm that Inhibits Black Stem in Alfalfa..... 49
Use of Chloroplast Components to Distinguish Between Alfalfa Populations..... 49
Development of Germplasm that Decreases Seed Chalcid Attack of Alfalfa..... 49

V. Wind Erosion Control Research Unit - Wind Erosion Control Methods

Field Testing of the Wind Erosion Prediction System (WEPS) 1.0 and Additional Training..... 54
Modifications to WEPS 1.0..... 55